BOSTON UNIVERSITY

College of Business Administration

THESIS

The Use of Color in Industrial Management

by

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submitted in partial fulfillment of
the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

PREFACE

The use of color, in all its various forms, in business today, presents new and interesting problems in every phase of management activity. Because of this universitility of color it was deemed advisable to limit this discussion to those phases of color-use concerning industrial management. The author has tried to combine the work of many men and companies into one compact discussion of the use of color in industrial management so that the reader may get an overall impression of the subject and its scope. It must be remembered that the science of color engineering is comparatively new and that at the present time there is little assembled material available to the reader where a general discussion of all the uses of color in industrial management may be found. It is felt thatthis discussion will help to fill this gap.

The author wishes to express his appreciation to Professor William L. Lomax, Professor of Industrial Management, College of Business Administration, Boston University, for his advice, counsel and assistance in the preparation of this thesis.

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INTRODUCTION

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The terms "Color Conditioning" as used by E. I. DuPont de Nemours or "Color Dynamics" as used by Pittsburgh Plate Glass Company, the two leaders in the field of color application to industrial life, are almost identical. These two companies have spent many thousands of dollars in research and are today sending their engineers all over the country, helping industry apply color to industrial activity.

"Color Conditioning" as defined by DuPont is,

> A scientific plan for painting an entire industrial plant - to increase production by raising operating efficiency - to improve quality of output by reducing the number of 'rejects' or 'seconds' - to make seeing conditions better by eliminating glare, sharp contrast and camouflage - and to lift employee morale by changing the

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> working environment to a more comfortable and cheerful one.[1]

The most important point in this definition is that it is a scientific plan. If "Color Conditioning" or "Color Dynamics"[2] is to be effective then colors must be used wisely and with restraint. Random use of color without regard for functional value is both objectionable and detrimental. Color specialists have devoted years to the study of industrial interiors, and while they may disagree on specific applications, they unite in recommending restraint in the use of color.

The objectives of "Color Conditioning" are three in number, according to the Pittsburgh Plate Glass Company:

1. To promote continuity of employment.
2. To improve efficiency of operation.
3. To maintain quality of production.

> Color Dynamics can make a real contribution toward these three objectives. Color Dynamics means more and better work per man-hour and more man-hours per man.[3]

1. "DuPont Color Conditioning for Industry", E. I. DuPont de Nemours and Company, Inc., p. 3.
2. Because of the aforementioned similarity of meaning between these two terms, the first, "Color Conditioning", will be used throughout the remainder of the report.
3. "Pittsburgh Color Dynamics", The Pittsburgh Plate Glass Company, pp. 2-3.

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Industry has spent millions of dollars on time and motion studies to minimize body fatigue and increase production efficiency, but up to now,except for improved illumination, practically nothing has been spent to save workers from eye fatigue. Past experience, built up over a period of years,has brought about many changes as a result of time and motion study that to the industrialist and management of that time seemed trifling. The length of a shovel handle or a screw driver, the height of a chair or stool raised an inch or two, the grip on a wrench changed- - - tremendous trifles, yes, but the productivity of the worker affected by the change goes up 5, 10, or 15 per cent. This new science of color conditioning deals with one of these tremendous trifles - COLOR. At first thought it is hard to believe that the mere application of a different color on a machine, wall, ceiling, form, chart, tool or rest room could have an appreciable influence on a worker's output or morale. But when it is remembered that many of the advancements made in industrial efficiency by time and motion study which are now considered to be common practice were once termed trifles and took time to be accepted by industry, we can more readily see the part color can play in industry today. Color, like time and motion study, has been considered a trifle and it is only in the last five to ten years that its value has really

been appreciated. Color can do much to aid industry meet the demand of greater production and lower cost.

II. Light and Color

Light and color[1] are co-partners in illumination. One cannot be considered without the other. It was in the study of illumination that color was first appreciated. Natural and artificial illumination go hand-in-hand with intelligent use of color to improve seeing conditions. Brightness of any surface depends on the amount of light directed toward it and the reflection factor of the surface. Inasmuch as paint is the most common and controllable medium for covering surfaces, colored paints assume great importance in obtaining good lighting and seeing conditions. Any lighting specialist knows that a high reflecting paint is a formidable ally not only in conserving light but in helping to achieve good seeing conditions. (See Exhibit 1, page 10).

Satisfactory seeing conditions depend upon several brightness-ratios.[2]

1. While light and color are perhaps the most important factors in illumination, others such as size and shape of objects, texture and finish of surfaces, etc. will effect lighting and cannot be overlooked in a complete survey or plan for illumination improvement.

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1. The brightness ratio[1] between the fixtures of a general lighting system and their background, should be as small as possible.

2. The brightness ratio between the visual task and its immediate surroundings should be as low as possible. For example, this page can be read with greater ease and accuracy when its immediate surroundings, such as a desk-top, are of approximately the same brightness as the page.

3. The brightness of the specific task should be as great as any major areas in the entire visual field.

4. Work details in many cases must be seen silhouetted against a background whose brightness is controllable.

It is only after good seeing conditions have been achieved that color opportunities should be fulfilled. Considerations of color are generally secondary to the major achievements of brightness which results from the cooperation of light and the reflection factor of paint or other finishes. This is the basis that Matthew Luckiesh, D.Sc., D.E., of General Electric often referred to as "the father of the science of seeing", believes that color should be used by industrial plants. Dr. Luckiesh believes that if color is to be effectively applied to walls and ceilings to aid in illumination it must have a reflection-factor of

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III. The Powers of Color

Another group of factors that has done much to influence the principles of color dynamics or color conditioning are the powers that certain colors have in producing esthetic and psychological reactions in human beings. Colors have the power to convey the ideas of coolness, warmth, lightness, cheerfulness, smallness, largeness; they can stimulate a worker or they can make him feel depressed. It is these various reactions to color that make color engineering so difficult and which demand such careful and detailed analysis of all factors in an industrial plant, before a color scheme can be determined. In the spring of 1947, Harvard University in Cambridge, Massachusetts had a large hall in the School of Architecture repainted. Much time was spent in selecting a suitable color. However, this selection was from small patches, and the color chosen was approved by all who saw it. At first when the hall was completed reaction to the color seemed to be very favorable, but soon the large expanse of this particular color became depressing and students and faculty alike almost refused to use the room and growled when their classes were scheduled there. The room

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was soon repainted in a different color and the unfavorable reactions disappeared.

One more example of the power that color has over people's reactions is typified by the following instance. A large manufacturing concern in the east began to receive many complaints from their women employees that their newly decorated cafeteria was chilly. The cafeteria had just been repainted and refurnished with a color scheme calling for light blue walls and accessories. A check on the temperature showed it to be a constant 72 degrees. The management of the company was much perplexed by these complaints and hired a color engineer. The engineer recommended that orange slip covers be placed on the chairs and that a base board and dado of orange be added. As soon as this was done, all the complaints disappeared; the temperature was still a constant 72 degrees. Blue has the power to make things seem cooler while orange has the power to make things seem warmer.[1,2]

Thus in applying the principles of color conditioning or color dynamics and color usage it is many times necessary to remove color rather than add it. However, it is not necessary for the industrialist to know why colors create the reactions they do nor just what

1. "Color Strategy for Wartime America", Time Tested Paint Laboratories, 1943, p. 11.
2. See Exhibit 2, page 11 for a listing of various colors and their powers.

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makes color, for this has been very exhaustively worked out by physicists. The industrialist should know the principles of color strategy as applied to people and things. With these principles it is possible to take advantage of color's many contributions to industrial advancement. Practically all the applications of color are formed around its amazing ability to make sight one of the strongest senses in a plant. Of all the five senses, sight, smell, taste, touch, and hearing, there is only one that is most used so far as industry is concerned and that is sight. There is no need to determine what is shown as is the case with a printed paragraph, nor is there any need for the brain to change the printed words into ideas and ideas into action. With color all that is necessary is that the brain match the color to a pre-determined reaction. Yet, while color can make the brain see clearer and quicker it can also deceive the brain and make it believe and act as if something else were the case. It is these two reactions to color that the color engineer makes great use of in setting up color codes and devices for industry.

For a more complete discussion of the factors and principles of color, light, brightness and color psychology as used by the color engineer, the following references will be helpful.

Luckiesh, Matthew, "Light, and Color in the

Work-World, U.S. Gutta Percha Paint Company, 1945, 22 pages.

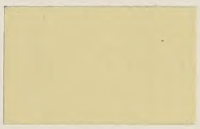
Luckiesh, Matthew, "Brightness Engineering", General Electric Company, Research Lighting Laboratory, 10 pages.

EXHIBIT 1

Reflection Values of Paint Colors Selected for Their Adaptability to Industrial Use*

WHITE
Ref. Val. 84%

CREAM
Ref. Val. 68.8%



IVORY
Ref. Val. 66.7%

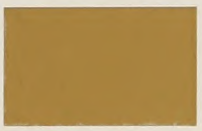
YELLOW
Ref. Val. 57.0%

LIGHT PINK
Ref. Val. 66.5%

FLESH
Ref. Val. 51.6%

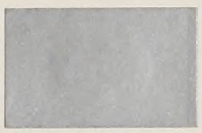
DARK RED
Ref. Val. 13.8%

BUFF
Ref. Val. 51.5%



BROWN
Ref. Val. 27.5%

LIGHT GRAY
Ref. Val. 51.5%

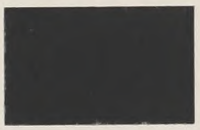


ALUMINUM GRAY
Ref. Val. 41.0%

LIGHT GREEN
Ref. Val. 45.2%

SAGE GREEN
Ref. Val. 36.3%

LIGHT BLUE
Ref. Val. 36.4%



DARK BLUE
Ref. Val. 8.4%

DARK GREEN
Ref. Val. 9.2%

The accompanying colors readily show that, with the exception of yellow, colors will not yield good reflection values if far removed from white.

*Light reflection efficiencies for this chart determined by Munsell Color Co., Inc.

Readings obtained on a photometer in which the light falls on the sample normally and is reflected at forty-five degrees. This method measures essentially the diffused reflection from a surface as distinguished from glare or mirrorlike reflection.

Source: New Jersey Zinc Company

EXHIBIT 1

Economical Illumination from Light Reflecting Walls and Ceilings . . . . Depends on Paints of Permanent Whiteness or Unfading Tint.

. . If walls and ceilings are to reflect the maximum amount of both natural and artificial light they must not discolor or fade. Because white has the highest light reflection efficiency, paint must be based on pigments of permanent whiteness.

. . The most widely used pigments for white paints are Zinc Oxide and Leaded Zinc Oxide Pigments. They are non-darkening and permanently white. They make white paints whiter when. And because the permanence of tints depends on the white pigment base, Zinc Pigments to paints also have assurance of permanent color.

. . Zinc Oxide paints are washable . . . their smooth, tough surface is not affected by the periodic washings which preserve light reflection efficiency.

. . We shall be glad to tell you how high light reflectant Zinc Pigments will help solve your illumination problems.

Source: New Jersey Zinc Company

EXHIBIT 2

THE POWERS OF COLORS

Color	General Appearance	Mental Associations	Direct Associations	Objective Impressions	Subjective Impressions
Red	Brillant, Intense, Opaque Dry	Hot Fire Heat Blood	Danger	Passionate Exciting Fervid Active	Intensity Rage Rapacity Fierceness
Orange	Bright Luminous Glowing	Warm Metallic Autumnal		Jovial Lively Energetic Forceful	Hilarity Exuberance Satiety
Yellow	Sunny Incandes- cent Radiant	Warm Sunlight	Caution	Cheerful Inspiring Vital Ecelestial	High spirit Health
Green	Clear Moist	Cool Light Nature Water	Go Clear	Quieting Peacfull Refreshing Nascent Calmness	Ghastliness Disease Terror Guilt
Blue	Deep Soft Transparent Wet	Cold Sky Water Ice	Service	Subduing Melancholy Sober	Gloom Fearfullness Furtiveness
Purple	Deep Soft	Cool Mist Darkness Shadow	Mourning	Dignified Pompous Mournful Mystic	Loneliness Desperation Depressing

EXHIBIT S

THE HOMEWAY OF COLORS

Color	General Impression	Masculine Feminine	Associations Direct Indirect	Impressions Opposites	Emotions Symbolism
Red	Exciting, Stimulating, Warm, Active, Hot, Fire, Blood, Day	Masculine	Danger	Hot Fire	Anger, Passion, Excitement, Love, Energy, Courage, Strength, Power, Aggressiveness
Yellow	Sunny, Warm, Inviting, Cheerful, Light, Gay, Hazard, Caution	Masculine	Caution	Cheerful Gay	Happiness, Joy, Hope, Intellect, Energy, Vitality, Wisdom, Deceit, Jealousy, Cowardice
Green	Cool, Refreshing, Restful, Nature, Grass, Water, Trees, Spring, Go	Feminine	Go	Restful Quiet	Harmony, Freshness, Fertility, Youth, Growth, Hope, Envy, Inexperience
Blue	Deep, Cool, Quiet, Sky, Water, Sea, Distance, Cold, Ice	Feminine	Depth	Deep Cool	Confidence, Security, Loyalty, Truth, Wisdom, Faith, Dignity, Conservatism
Purple	Dignified, Royal, Rich, Mysterious, Gloomy, Sad, Lonely	Feminine	Royalty	Royal Rich	Mystery, Wisdom, Dignity, Power, Sadness, Melancholy, Gloom
Orange	Warm, Exciting, Stimulating, Sunshine, Autumn, Fall, Fire	Masculine	Autumn	Warm Exciting	Energy, Warmth, Cheerfulness, Vitality, Flamboyance, Extravagance
Brown	Earthy, Rich, Warm, Autumn, Leaves, Wood, Soil	Masculine	Earth	Earthy Rich	Reliability, Dependability, Stability, Endurance
Gray	Dull, Depressing, Lifeless, Old, Sad, Cloudy, Smoke, Fog, Rain	Feminine	Old	Old Lifeless	Sadness, Depression, Boredom, Indecision, Uncertainty, Old Age, Decay
White	Pure, Clean, Cold, Snow, Light, Sterile, Hospitals, Weddings	Feminine	Purity	Pure Clean	Innocence, Purity, Virginity, Faith, Hope, Peace, Cleanliness, Sterility
Black	Mysterious, Dark, Sad, Death, Night, Fear, Evil, Mourning	Masculine	Mourning	Dignified Formal	Impressive, Mysterious, Sophistication, Death, Evil, Fear, Sadness, Grief

CHAPTER II

COLOR CONDITIONING A PLANT

Color conditioning the plant is divided into three phases; first as applied to color conditioning the machines; second, color conditioning the walls and ceilings; and third, color conditioning the floors and aisles.

I. Color Conditioning of Machinery

Many manufactuers fail to provide adequate light and safe working conditions for their workers to perform the assigned tasks. Machinery may be so camouflaged in full colors that it and the material being worked upon blend into a solid, dark mass. Contrasts are lacking, the worker's eyes are strained and production is slowed down. In many cases, danger spots are not emphasized and workers are injured causing labor turnover, delayed production and expense.

For years machines in industrial plants have generally been painted black or a dark grey. They are dull and drab, absorbing much of the light that should be used for seeing. Of even greater importance is the lack of distinction between the machine and its operating parts - and between these parts and the material being worked. To solve this problem, manufacturers tried many

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things - one of them being color.

The idea of painting machinery in colors dates back at least a quarter of a century. The reasons for doing it, however, were little understood until comparatively recent years. One of the most detailed studies along these lines was conducted by Messrs. Arthur A. Brainerd and Matt Denning under the sponsorship of the Philadelphia Electric Company and the Finishes Division of the E. I. DuPont de Nemours Company.[1]

This study was conducted on a small punch press and a power shear, under both incadescent and mercury lighting equipment. Illumination of the working area was maintained at 30 foot candles.

Over a period of several months the following colors were tested on the shear and punch press.

Shear	Punch Press
Battleship grey	Battleship grey
Aluminum	Yellow
Light Green	Light Blue
Light Grey	Light Buff
Light Grey with Dark Green outer surfaces	Medium Grey with Light Grey background
Light Grey with Medium Grey background	Light Buff with Medium Grey background
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Each color was given three tests under both types of light and on each machine. The first test was a measurement of the light falling on the working surfaces of the machine and the light reflected them them. In taking these readings the working surfaces of the machines were divided up into zones, each zone having an area of one square foot. Accurate photometric measurements were taken of the illumination in foot candles of light falling on the surfaces and brightness in foot candles of light reflected back from the surfaces, for each color. The results of this tests are shown in Exhibit 3 on page 33. It was indicated by the test that on the shear light grey and aluminum were nearly alike under mercury light. Under incandescent light, aluminum was not as consistent a performer. In either case, reflecting properties of light green were high but light buff was determined to be the best of all colors tested. Yellow failed to perform as well as the other colors under incandescent light on the punch press. All the colors used on the punch press were nearly alike under mercury light. Under incandescent light, however, light buff proved to be the best.

The second test was one to study the effect on production of colors applied to machines. Time-study records were made of three simple jobs performed by an experienced operator under both types of light and for each color tested. The results of the average of the three

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studies for each color are shown in Exhibits 4 and 5, pages 34-35 . This test showed that for shear operations there is little to choose between light buff on medium grey and light grey or green as far as production was concerned. An interesting note was discovered in the drop in speed with light grey when the bulk of the machine was painted dark green. An explanation of this is perhaps the marked contrast in brightness within the range of vision.

The last test to be made was a psychological study of fiteen workers including two foremen concerning each color used. The study was based on a questionnaire consisting of six questions, applying to each color under both types of light. The results of this test are shown in Exhibits 6 and 7, pages 36-37 . It is interesting to note that in the comparison of test colors with the original grey, 100% of the men said they could see better with light buff, 28.6 said buff was less tiring and the remainder said that there was no fatigue difference. All the men thought the light buff color was a safer color.

The conclusions to be drawn from this study are that light buff with light grey a close second, is the most suitable color for working with iron or steel material. But more than the definite answer were the

studies for each color are shown in Exhibits 4 and 5, pages 34-35 . This test showed that for sheer operations there is little to choose between light buff on medium grey and light grey or green as far as production was concerned. An interesting note was discovered in the drop in speed with light grey when the bulk of the machine was painted dark green. An explanation of this is perhaps the marked contrast in brightness within the range of vision.

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general ones brought forth. First, soft contrasts[1] are easier on the eyes than abrupt changes. Secondly, making the tool area slightly lighter than the surrounding area does tend to concentrate the attention on the work. Thirdly, such a contrast does highlight danger and make the operation safer.

From studies such as this a science of painting machinery was developed by which machinery is colored. The first job of color is to separate the critical from the non-critical parts of the machine, and if possible at the same time visually divorce the critical from the material being worked upon. This is accomplished by first making the critical parts stand out by "spotlighting", from the non-critical by applying a soft, quiet color of the correct brightness. One color expert recommends the use of light grey while another recommends the use of a medium green. Still another recommends that the machine be painted the same color as the wall dado in the room where it is located. The main idea, however, is to have the color produce a receding effect and to be quiet, unobtrusive and restful.[2]

1. Soft contrasts are those which allow the eye to change easily from one to the other without any great amount of effort, such as progressing from a light blue to light buff in contrast to a change from red to white. The light blue and light buff are said to be a soft contrast.
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2. See Exhibit B, pages 38-41 for examples of machine painting.

The next step in color conditioning the machine is to select a second color, to paint the critical areas. This is a focal color that immediately draws the worker's attention to the operating or critical parts of the machine. It focuses the worker's attention actually where it should be, arrests his eye and reduces the unnecessary travel and time necessary to pick out the working area when the machine is all one monotonous color. This spotlighting provides maximum visibility at the critical area, but still it must not be distracting but rather blend with the surrounding area and provide sufficient contrast with the machine body paint. Light buff, cream, light green are recognized by practically all the leading color engineers as having the greatest functional values for critical work areas. It is a color that must come forward from all those around it and yet still not be distracting nor reduce the brightness needed for the work.[1]

Still further this focal or spotlighting color must be selected with an eye to being in contrast with the material being worked upon. The operator should not have to strain to see where the material ends and the machine begins. Thus, a light grey focal color is completely wrong if the material is aluminum or stainless steel. Rather a light buff is recommended for this

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application. Light green is considered best as a focal color for brass, copper, bronze, wood and similar materials. To assist industrial managements in selecting the proper focal and background colors, several handy devices have been designed. One such device works on the idea of a small slide rule. The device is in the form of an outer envelope, open at each end, so that a tab may be slid back and forth with the envelope. The outer envelope has several holes in it through which various colors can be made to appear by pulling or pushing the inside tab. By placing a sample of the material to be worked upon over one of these windows and sliding the tab to produce different color combinations, the various contrasts can be seen and the best one determined for the application.[1]

The Pittsburg Plate Glass Company has also devised one that is based on several cards. These cards are finished in the various receding colors and have a hole in the center. This hole is filled alternately with the different focal colors. Thus a piece of material to be worked upon is placed over the hole in the card that has been selected for the receding color. Then the various focal colors are placed in the hole which immediately shows the contrast existing between it and the material

1. Brainerd, Arthur A. and Massey, Robert A., "Salvaging Waste Light for Victory", 1942. pp. 11-12.

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II. Color Conditioning the Walls and Ceilings

The second phase of color conditioning must move hand in hand with the first. The visual field of the machine operator is not limited to his machine. It extends to the adjacent wall, to the floor and ceiling areas behind the machine and to any area the operator sees when he raises his eyes from the machine. Hence, it is necessary to properly select the color for the surrounding field of vision to eliminate several contrasts and glare so that the eyes will find little difficulty in refocusing on the machine and the work areas. The movements of the eyes are controlled by seven muscles. Every time the eye moves in any direction muscular action takes place. When the iris contracts or expands, that also requires muscular effort. Eye muscles get tired just like the muscles in the arm, leg or back, but have the curious faculty of not showing that tiredness in the eye itself but in other parts of the body, such as digestive upsets, headaches, nervous and many other disturbances. Eye fatigue slows a worker down and both quality and quantity of production slow down.[2] Thus the fewer eye

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motions we demand of our workers the more efficient and productive they will be.

Every time the worker lifts his eyes from his machine and sees a brilliant, glaring wall or sees glaring objects because of dirty or dark walls, his eyes must adjust themselves. Then when he returns to his machine the eye must again go to work and make another readjustment. As a consequence the eye becomes tired and the worker's production begins to fall. Color conditions act to eliminate this type of contrast within the worker's range of vision. There is a uniformity of brightness within his seeing range at all times that keeps eye motion at a minimum and in fact tends to rest and sooth the eyes.

Here more than any other place in the plant the powers of color set to work to make the worker feel and act in strange ways. The average person will under-estimate the temperature of a blue room and over-estimate the temperature of a red room. Green is a calming and restful color while red stimulates and causes people to react quicker and soon become nervous if under its influence too long. Morale can be built up through the proper application of color to the shop and to rest rooms and cafeterias. We can use color to hide things and to bring other things out where they will be seen. Thus in selecting colors for walls and ceilings no one factor governs

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our choice, rather it is the best compromise between all the factors. Let us look at these factors one at a time remembering that in actual practice we must be considering them all at the same time.

A. As a background for our already color conditioned machines.

This color is selected with the idea in mind to reduce the background to one of complimentary color so that the eye will not meet glaring or strong colored objects or walls to distract the eye and produce eye fatigue. The eye has the phenomenon, if overstimulated by one color, of registering the opposite or complimentary color as a means of adjustment. This interesting visual adjustment is called after-image. In an inspection room of a North Caroline cotton mill manufacturing blue denim, the girl inspectors scanned the blue material hour after hour. The inspection room had been painted white by the management in order to give the girls the maximum amount of light. But when the operators took their eyes from the cloth to rest them the white walls turned peach and serious eye fatigue developed. When the girls returned their eyes to the material it took several minutes to re-adjust to the blue color. Color engineers successfully eliminated much of the eye fatigue and greatly increased the time the girls could work on the material by providing

what the eyes demanded - peach walls. The eyes had little trouble readjusting to this color as it is the complimentary color of blue.[1]

Furthermore, this background for the machines must also be such that the critical areas are not lost against it. The machines should not be lost in the background nor should any other items of equipment. Thus the background must offer contrast to the machine and its critical working area and at the same time be restful to the eye. Color engineers state that a brightness ratio of about 1 to 5 is maximum between machine and walls.[2][3]

B. What effect will illumination have on the colors?

In selecting colors to be used in industrial plants the type of lighting plays an important part. Color takes on different hues under different types of lighting. Under incandescent lights, blues fade or become darker, reds assume a yellowish or golden tinge. Under mercury lighting red becomes a deep maroon with an almost brown cast; bright oranges give a pale washed tan; yellow becomes bright and vivid; violet and green

1. Stouffer, Lloyd, "Color Punches the Time Clock", Popular Science Monthly, June 1947, p. 126.

2. See footnote, page 5.

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B. What effect will illumination have on the colors?[3]

In selecting colors to be used in industrial plants the type of lighting plays an important part. Color takes on different hues under different types of lighting. Under fluorescent lights, blues fade or become darker, reds assume a yellowish or golden tinge. Under mercury lighting red becomes a deep maroon with an almost brown cast; bright oranges give a pale washed tan; yellow becomes bright and vivid; violet and green

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were only intensified, while black and white were unchanged. In considering color under fluorescent light we must check it under three types of tints, as fluorescent light may be daylight, 3,500° white, or soft white. Daylight fluorescent gives the closest approximation of true natural light as can be found and color is not apt to be changed too much. 3,500° white has a tendency to over-emphasize the yellow and green shades. The soft white, having a slight pink to it, emphasizes the blue and pink colors and reduces the hue of yellow and green. For a more complete analysis of what the various types of light may do to colors, Exhibit 10, page 43 shows the reactions and observations of a group of workers to colors and lights in a large eastern manufacturing plant.[1]

C. What effect will the colors have on illuminations?

Lighting experiments have proven that color schemes used in industrial plants for walls and ceilings must have a minimum of 75% of the light reflected from the ceiling and 50-60% from the walls in order to provide the necessary amount of light for proper working conditions.[2] While white reflects the most light, certain shades falling well over 80%, it is not necessarily

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c. What effect will the colors have on illumination?

Lighting experiments have proven that color schemes used in industrial plants for walls and ceilings must have a minimum of 75% of the light reflected from the ceiling and 30-80% from the walls in order to provide the necessary amount of light for proper working conditions.[2] White reflects the most light, certain shades falling well over 80%, it is not necessarily

1. Williams, Harry L. op. cit., pp. 124-125.

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wise to paint everything white. For many years white has been accepted as the best color for walls and ceiling where vision and brightness were important. One large paint manufacturer in this country has spent many thousands of dollars expounding the values of white for this purpose. White unrelieved by color had a tendency towards coolness and in many cases sets up a glare factor in a room that receives to much natural light or where dirt and grime are allowed to accummulate on walls and fixtures. Walter G. Holmes in "Applied Time and Motion Study" makes the statement,

> Eye fatigue is minimized when the light comes from a cream or ivory tinted light source, hence these tints should be used for walls and ceilings.[1]

Research in some factories has shown that white walls and ceilings actually tend to reduce visibility. This is particularly true where the major field of vision is bright and the area in which the employees must work is dim. Records of these studies show that in some instances white walls have lowered visibility as much as 25% even though foot candles of light had been increased 5 to 10%. White in a strong light tends to blur the vision. One such study to test the values of color was conducted by Arthur A. Brainerd and Robert A. Massey [2]. This test was made under very exacting conditions in a controlled room.

1. Holmes, Walter G., "Applied Time and Motion Study", New York, "The Ronald Press Company, 1938, pp. 101-104.
2. Brainerd, Arthur A. and Massey, Robert A., op. cit. p.1

Various shades of paint were tried in different combinations on walls and ceilings. Lighting in foot candles was maintained constant throughout the tests. Exhibit 11 page 44 shows the results of the test and the colors used. Conclusions reached in this study were as follows:

1. By means of scientific use of color, it is practical to increase the illumination from most lighting systems 100% without any change in lighting equipment or wattage.

2. Satisfactory hues may be secured without serious sacrifice in reflection properties.

3. Floor and table finishes of 65% reflection - factor value or even higher are practical.

4. That carefully selected contrast hues will effectively augment brightness contrast for comfortable, accurate continuous vision.

Colors recommended by this study were light buff, light green and light grey. Green seems to be the most universally accepted color for walls as far as lighting qualities are concerned. However, most soft, pale hues of fixed reflectance values have been found advantageous as background colors within the line of a worker's vision. They should not be clear bright colors as this is distracting. We are not after creative effects such as would be created in the home but rather a specific and utilitarian

purpose.

Dados, surfaces at the base of walls and generally running up the wall about one third of its height, can be painted a fairly deep color for ease of maintenance. Where possible this color should harmonize with the surrounding colors. Some color specialists recommend that the walls be painted in color up to eight feet and the rest of the wall to the ceiling be painted white.

Most experts are agreed on the fact that ceilings, generally should be painted white. Matthew Luckiesh one of the foremost authorities on paint and light recommends white almost exclusively.[1] The ceiling is one of the most important light reflecting surfaces and it is agreed that white reflects more light than any other color. An exception to the white ceiling would be in such rare instances as when the operator's work compelled him to look upward.

Another factor to be considered in ceiling painting besides the light reflection value is that of making the ceiling recede in low ceiling rooms and also to remove a cluttered up look from numerous pipes and beams. Such a clutter seems to "bear down" on the worker and quite possibly effect his production. A color like light blue

1. Luckiesh, Matthew, "Light and Color in the Work-World", 1945, pp. 18-22.

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which suggests the outdoors or the sky can make the ceiling recede and at the same time hide the clutter of pipes, wires, and beams so that the worker is not conscious of their presence. The Army made use of this technique in painting the insides of tanks in light cool colors both to create the effect of coolness and to make the tank seem larger than it really was and therefore make the tank crew feel less crowded. The Navy had a similar situation on one of the Pacific Islands where a bomb-proof electric power plant had been built. The plant was a virtual dungeon, without windows and beneath the ground. Both civilians and Naval personnel found it hard to work in, even though it was well lighted and air conditioned. To overcome this oppressed feeling of being closed in, the Navy painted the upper walls and ceiling a soft greyed blue, suggestive of the outdoor blue sky. The result was the opposite of oppression and workers enjoyed working in the spacious-looking, cool vaulted rooms.

However, such a color scheme is only permissible by color where lighting conditions are poor and the ceiling is necessary as a light reflecting medium. Bright blue and light green, another accepted ceiling color, have reflective values of only 36.4% and 45.2% respectively, and therefore do not meet the specifications that ceiling paint necessary for light reflection work must have a reflection

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value of 50% or better.

D. The effect of the color on the workers

As is shown in Exhibit 2, page 11 colors have the power to make things seem what they are really not, and thus too seriously effect the worker's morale for the good or bad. Long narrow rooms can be made shorter by painting the end walls a contrasting color from the side walls. High ceiling rooms can be made to seem less lofty by painting walls in horizontal bands of color, each band getting lighter until it blends in with the light ceiling color. Hot rooms can be made to feel cooler by painting in shades of green and blue. Rooms with northern exposures can be made to seem lighter and sunnier by using shades of yellow and brown. Where work is hazardous, green walls can give the worker a sense of well-being.

The Cambridge Instrument Company of Ossining, New York, reported an immediate gain from color conditioning its plant of 15 per cent in production, 40 per cent in accuracy and most important, a 60 per cent decrease in absenteeism. The workers felt more cheerful and satisfied with their jobs.

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in a room can cause persons to become over excited, nervous and irritable, and also makes time pass more slowly. Purple is, to many persons, a depressing color and is associated with death and destruction.

E. The maintenance features of colors and paints must be considered.

Certain colors show dirt more readily than others and therefore are not practicable for some applications. Under changing temperatures and moisture content of the air some colors change hues. The surface to be painted must also be considered, as pigments may change color depending on the material in the surface. The color finally adopted must take into account the factors which affect the cost and upkeep of painted surfaces. The whole program should attempt to use as few colors as possible to cut down the number of colors the plant maintenance department must stock. The color scheme for the plant should be a coordinate whole and there should not be too great a contrast between rooms and areas of the plant.

Associate Editor of American Machinist, Harry J. Williams suggests that the industrialist ask and receive well studied answers to the following questions before undertaking any paint job in his plant.[1]

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1. Where is the paint to be used - on ceiling, walls or machines?

2. What kind of lighting is used - incandescent, mercury-vapor, fluorescent? What are the color characteristics of the light selected?

3. Is the paint durable?

4. How about maintenance? Does the paint clean easily? Does the paint get dirty quickly?

5. Are the combinations of colors pleasing. What is their effect on the worker and workplace?

6. How about the paint surface? Does it give the proper reflection values?

III. Color Conditioning the Floors and Aisles

Use of light colors below the normal eye level of a worker can be used to illuminate the work place and still not distract the workers. This principle of lighting has been applied by many of the large airplane manufacturers in areas where work must be done beneath the wings and fuselage. Also, the fact that numerous surveys have shown that workers are less apt to be careless and needlessly dirty where white or light or light colored floors exist is another reason why plants are adopting this type of painting.

In assembly areas where little grease, oil or dirt is accumulated from machine operations the use of a light colored floor can be of value and can be used to

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reduce the total amount of wattage necessary. However, as much of the work in our industrial plants entails the use of grease, oil, and other substances and where traffic is continuous, the cost of painting floors is a sheer waste of money.

The most that can be done with floor painting is painting aisles, steps, and dark corners with traffic marking paint, either yellow or white. These traffic strips can be used to separate work areas and also to provide safety aisles for the movement of trucks and materials. Painting dark corners and recesses white reduces the tendency of thoughtless employees using them as receptacles for debris.

Of all the uses of color this three-fold program of painting machines, walls and ceiling, and floors and aisles has gained great headway and is one of the most important uses of color today. Companies all over the country are finding the value of such procedures and are pushing it to the limits.

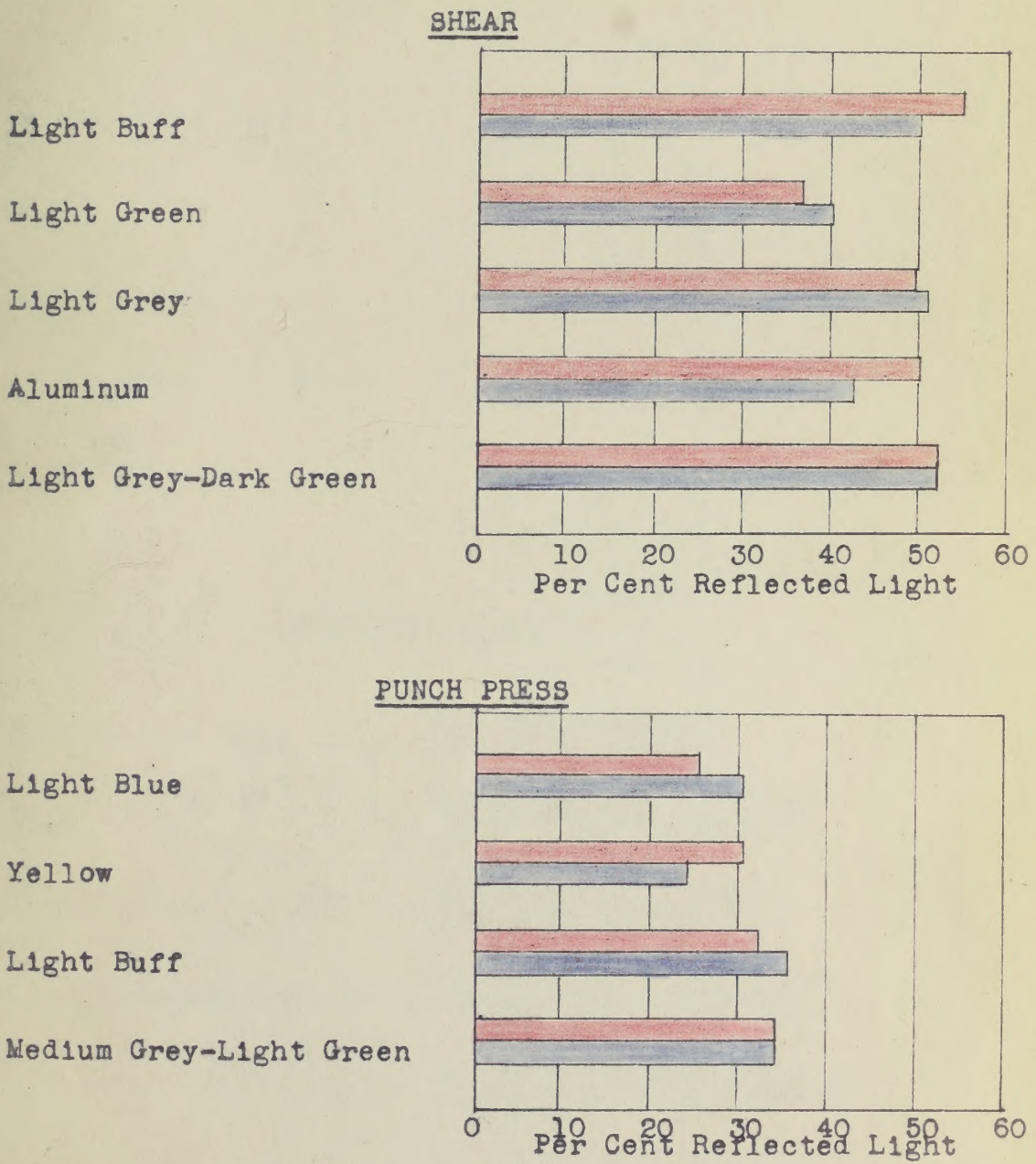
Factory managers are reporting production increases of 15 to 30 per cent, which they are attributing solely to the scientific selection of the proper colors to be used in routine factory painting. Color has found its way into all types of plants making all types of goods in many different ways. Textile mills and machine shops have

long seen the value, especially where there is extreme concentration of the worker at his task. Every bit of relaxation that can be obtained for the worker under these conditions is worth quality and efficiency for the company.

The science of color conditioning is not limited to just machines, walls and ceilings, and floors, and aisles, but has found its way into many other parts of industrial life. In many it is playing just as vital a part and in the rest it is gaining all the time. Color is versatile and simple to understand; therefore adaptable to all phases of industrial activity requiring simplicity and speed of understanding. The following chapters will discuss many of these additional uses of color.

EXHIBIT 3

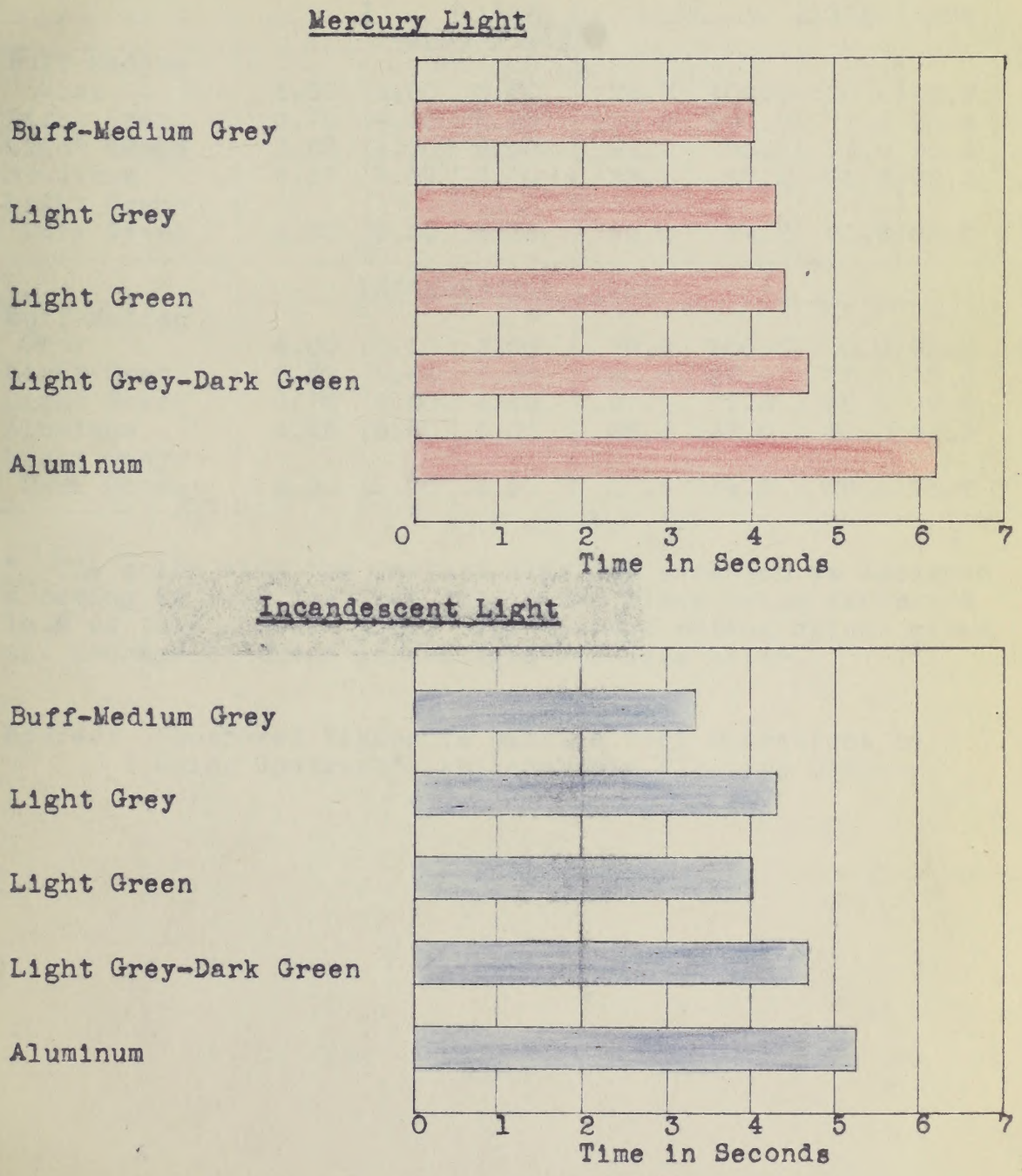
AVERAGE VALUES OF THE PER CENT OF LIGHT REFLECTED FROM MACHINE SURFACES



Source: "Improved Vision in Machine Tool Operations by Color Contrast" Philadelphia Electric Company.

EXHIBIT 4

AVERAGE OF THREE TIME STUDIES FOR DIFFERENT COLORS APPLIED TO THE SHEAR



Source: "Improved Vision in Machine Tool Operations by Color Contrast" Philadelphia Electric Company.

EXHIBIT 5

RESULTS OF TIME STUDIES

Color	Time in Seconds			Rating - Per cent*			
	Job 1	Job 2	Mark-ing	Job 1	Job 2	Mark-ing	Aver-age
	MERCURY LIGHT						
Buff-Medium Grey	4.80	4.00	3.70	78.7	100.0	100.0	92.9
Light Grey	3.78	4.00	5.20	100.0	100.0	71.2	90.4
Light Green	3.82	4.30	5.00	99.0	93.1	74.0	95.5
Aluminum	5.17	7.67	6.00	73.1	52.2	61.6	62.3
Light Grey-Dark Green	4.61	5.39	4.10	82.0	74.3	90.2	82.2
	INCANDESCENT LIGHT						
Buff-Medium Grey	4.60	3.10	3.00	79.8	100.0	100.0	93.3
Light Grey	3.67	5.44	4.00	100.0	57.0	75.0	77.3
Light Green	3.78	4.50	4.50	97.1	75.6	66.6	79.8
Aluminum	4.25	6.60	5.00	86.4	47.0	60.0	64.5
Light Grey-Dark Green	4.50	5.00	4.50	81.6	64.0	66.6	70.7

* The color with the fastest time for each job is assigned a rating of 100% for that job, other times being expressed in % of this fastest time. The average rating column gives the average of these percentages for each color.

Source: "Improved Vision in Machine Tool Operations by Color Contrast" Philadelphia Electric Company.

EXHIBIT 6

RESULTS OF PSYCHOLOGICAL QUESTIONNAIRE
MERCURY LIGHT

Question	Answer	Yellow	Light Buff	Light Blue	Med. Grey Light Grey	Alumi-num	Light Green	Light Grey	Light Grey Dark Green
Is paint more or less tiring than original?	More	100%	0%	42.5%	0%	25.0%	12.5%	0%	22.2%
	Less	0	28.6	42.8	25.0	37.5	12.5	12.5	0
	No diff.	0	14.4	71.4	75.0	37.5	75.0	87.0	77.8
Can you see better than with original?	Yes	37.5	100	100	87.5	71.5	100	100	77.8
	No	25.0	0	0	0	0	0	0	0
	No diff.	37.5	0	0	12.5	28.5	0	0	22.2
Can you work faster than with original?	Yes	0	57.1	67.0	75.0	60.0	85.7	87.5	77.8
	No	60.0	14.3	0	0	20.0	0	0	0
	No diff.	40.0	33.0	28.6	25.0	20.0	14.3	12.5	22.2
Is it easier to do better work than with original?	Yes	0	57.1	75.0	75.0	80.0	85.7	87.5	77.8
	No	84.0	14.3	0	0	0	0	0	0
	No diff.	16.0	28.6	25.0	25.0	20.0	14.3	12.5	22.2
Do you need more light?	Yes	80.0	100	100	87.5	100	100	100	100
	No	20.0	0	0	12.5	0	0	0	0
Do you think it's safer than before	Yes	- -	100	100	87.5	- -	100	100	88.9
	No	- -	0	0	12.5	- -	0	0	11.1

Source: "Improved Vision in Machine Tool Operations by Color Contrast"
Philadelphia Electric Company

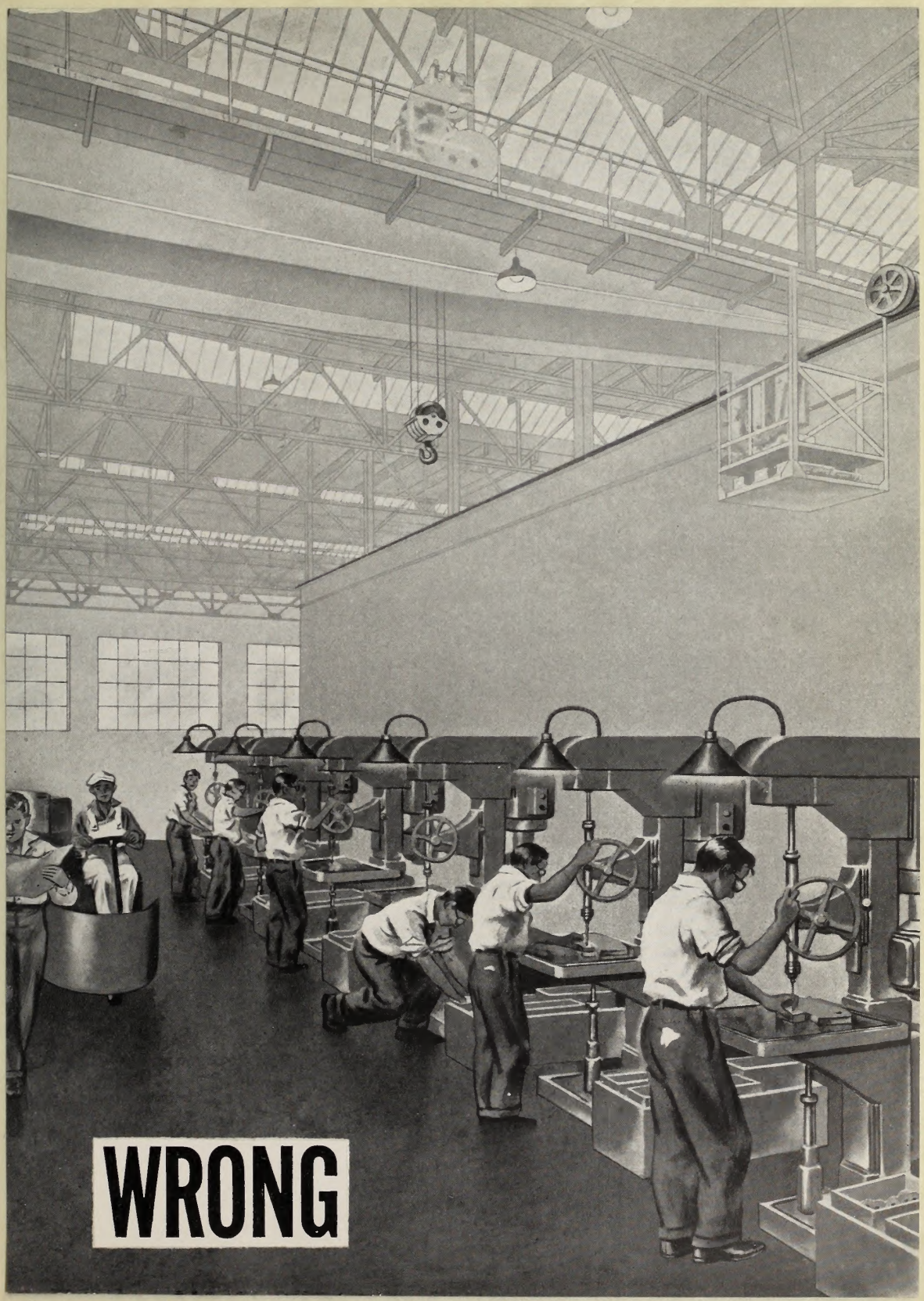
EXHIBIT 7

RESULTS OF PSYCHOLOGICAL QUESTIONNAIRE
INCANDESCENT LIGHT

Question	Answer	Yellow	Light Blue	Light Buff	Med. Grey Light Grey	Alum-num	Light Green	Light Grey	Light Grey Dark Green
Is paint more or less tiring than original?	More	100 %	28.6%	0%	0%	25.0%	12.5%	0%	22.2%
	Less	0	71.4	28.6	25.0	50.0	12.5	12.5	0
	No diff.	0	0	71.4	75.0	25.0	75.0	87.5	77.8
Can you see better than with original?	More	50.0	100	100	87.5	100	100	100	77.8
	Less	25.0	0	0	0	0	0	0	0
	No diff.	25.0	0	0	12.5	0	0	0	22.2
Can you work faster than with original?	More	0	67.0	57.2	75.0	80.0	14.3	87.5	77.8
	No	60.0	0	14.3	0	0	0	0	0
	No diff.	40.0	33.0	28.5	25.0	20.0	85.7	12.5	22.2
Is it easier to do better work than with original?	Yes	0	75.0	57.2	75.0	80.0	14.3	87.5	77.8
	No	83.5	0	14.3	0	0	0	0	0
	No diff.	16.5	25.0	28.5	25.0	20.0	85.7	12.5	22.2
Do you need more light	Yes	60.0	60.0	85.7	87.5	100	100	100	100
	No	40.0	40.0	14.3	12.5	0	0	0	0
Do you think it's safer than before	Yes	- -	100	100	87.5	- -	100	100	88.9
	NO	- -	0	0	12.5	- -	0	0	11.1

Source: "Improved Vision in Machine Tool Operations by Color Contrast"
Philadephia Electric Company

EXHIBIT 8a



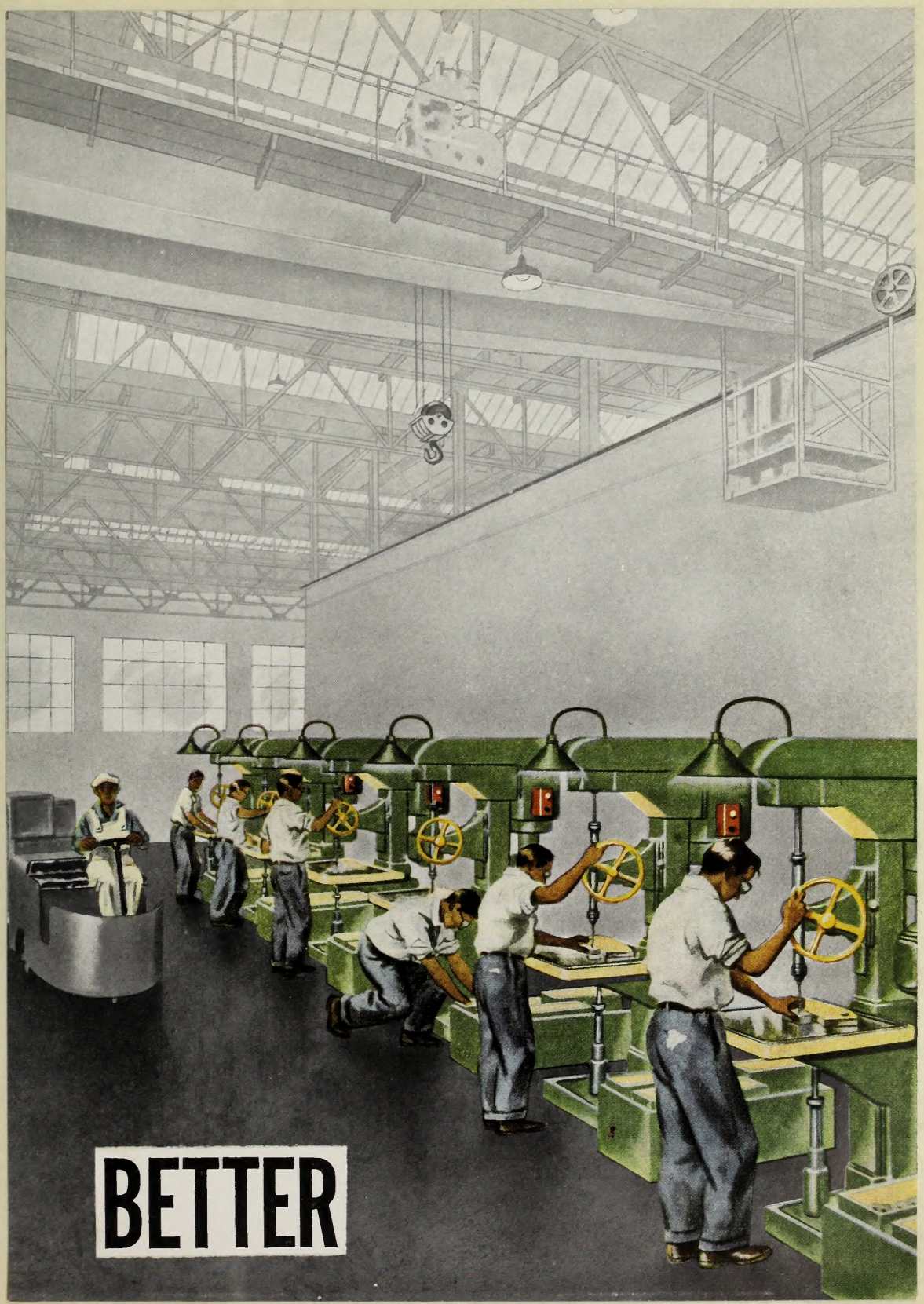
Courtesy Pittsburgh Plate Glass Co.

EXHIBIT 9a

COLO
DYNAMIC
Applied †

Courtesy Pittsburgh Plate Glass Co.

EXHIBIT 8b



Courtesy Pittsburgh Plate Glass Co.

ecreases Eye Fatigu

CAUSES OF EYE FATIGUE IN WORKERS..

TENSION...

Hold out your arm, and at the same time, tense the muscles of your fingers and forearm. Notice how quickly your arm grows weary. The same thing happens to a worker's eyes when the color of the material he is fabricating is too similar to the color of his machine. The eyes are required to differentiate between the material and the machine is a potent source of eye strain.

CONSTANT ADJUSTING...

Go from a dimly lighted room into a dark moving picture theatre. For a moment or two, you are so blind that you cannot find a seat. A worker who glances up from a light colored machine to a dark wall (or vice versa) has the same experience to a lesser degree.

Yet steady fixation upon a given task is fatiguing. Eyes are more comfortable when their direction of gaze changes frequently. Hence it is both natural and restful to glance up from work being done from time to time. If surroundings are dark, the effect of such glances will be to require the readjustment of the eyes to a different light intensity, and a second

EXHIBIT 8c

Courtesy Pittsburgh Plate Glass Co.

EXHIBIT 86

COLOR DYNA

The first job of Color D
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non-critical parts of th

FOCAL COLORS

The critical or operating pa
chine should be given a co
quickly to the eye, a color th
in strong contrast to the sta
critical parts of the machine.
as a *Focal Color*. It focuses
attention exactly where it sh
rests his eye and reduces t
travel which is bound to o
whole machine is a monoto
gray." As has been pointed
necessary eye travel throughou
day is a common cause of eye

RECEDING COLORS

While the critical part of the
come forward the non-critic
drop back. The widely used
does this to a certain extent

Courtesy Pittsburgh Plate Glass Co.

EXHIBIT 8d

Courtesy Pittsburgh Plate Glass Co.

EXHIBIT 84

Hsburgh Wallhide P B X Wall

for WALLS and CEILINGS

Courtesy Pittsburgh Plate Glass Co.

EXHIBIT 9

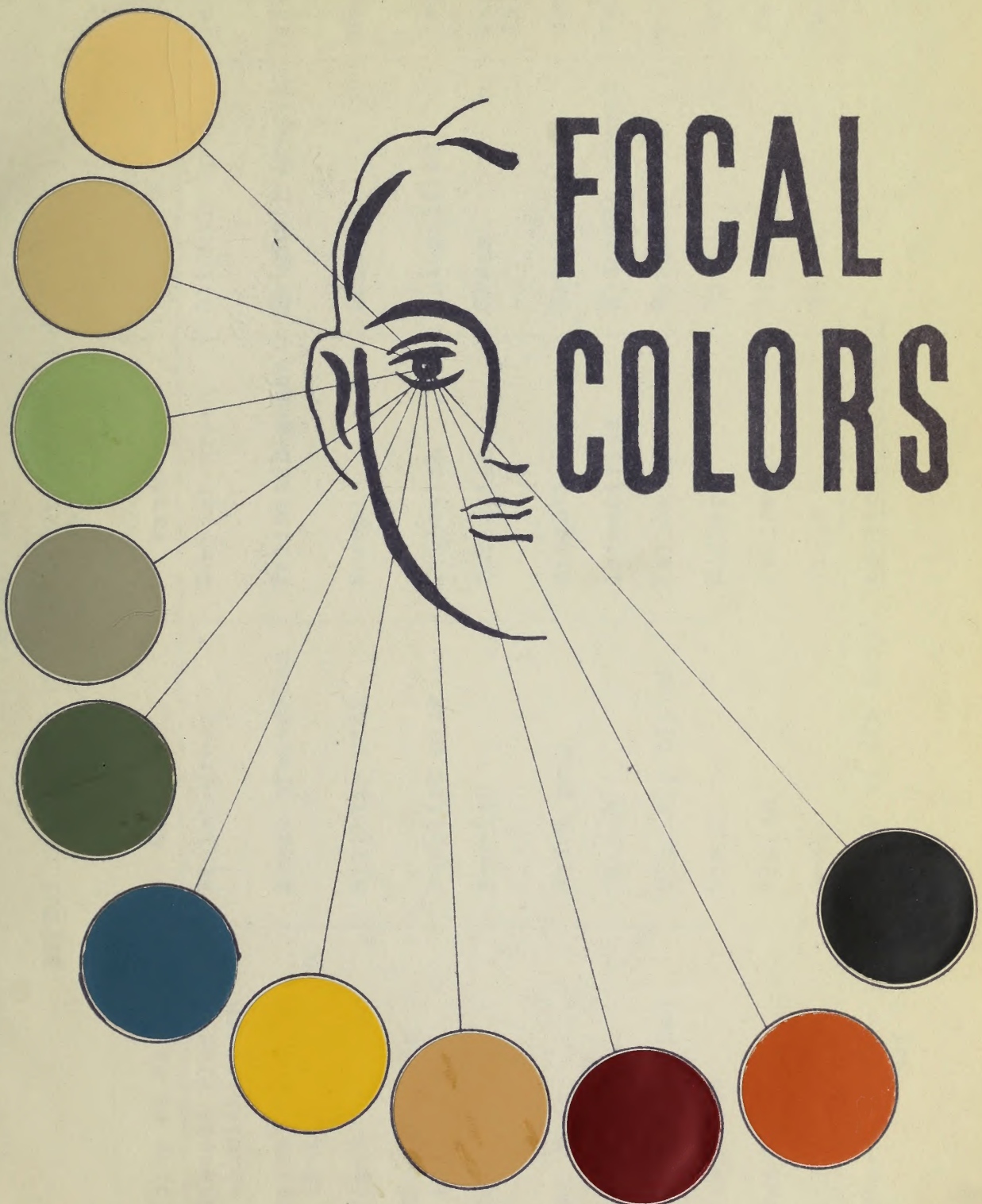


EXHIBIT 10

EFFECT OF FLUORESCENT AND INCANDESCENT LIGHTING
ON COLOR OF WALL PAINTS

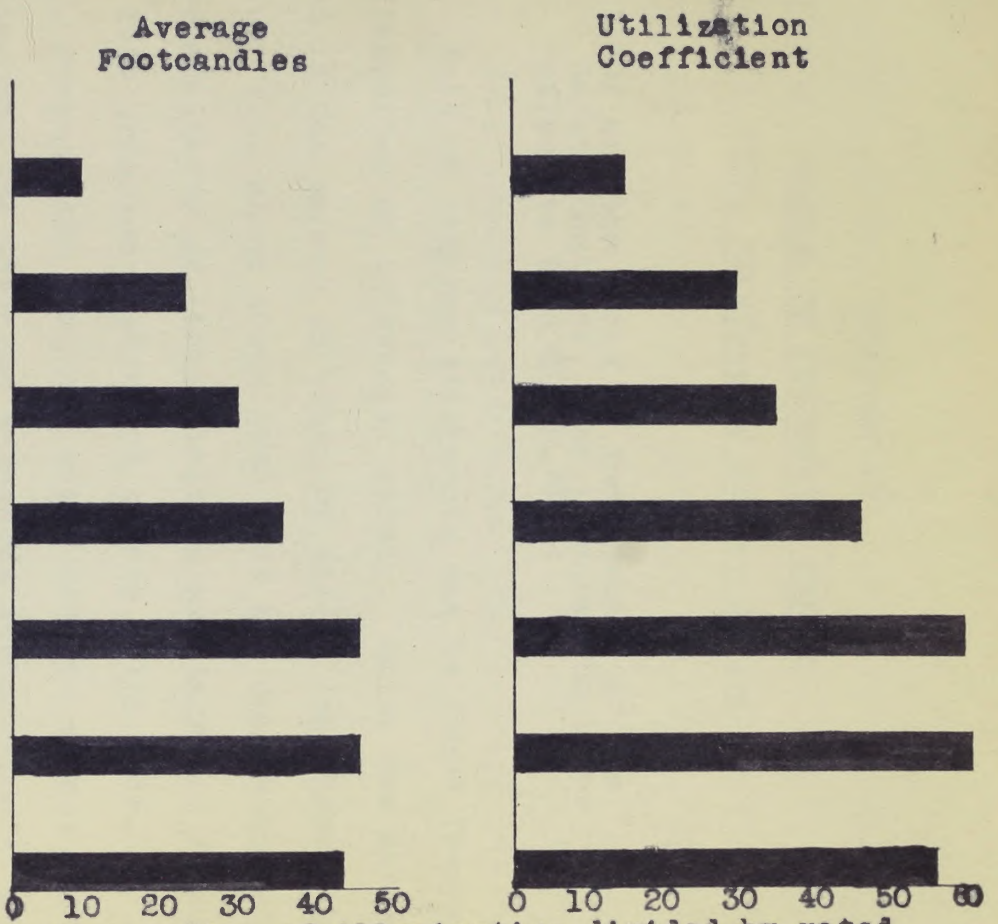
Color of Paints	Daylight Mazda F	3,500-deg.White Mazda F	Soft White Mazda F	Filament 100 Watt
Cascade Blue (bluish-green)	Bluish-green	Grayish-green	Slightly grayish	Yellowish
Palmetto Green (yellowish-green	Fresh blue-green	Yellowish-green	Slightly grayish	Yellowish
Peach	Slightly pink	Normal	Normal	Normal
Blossom Pink (pale pink)	Purplish pink	Yellowish	Intensified	Yellowish
Maize Tan	Grayish	Yellowish	Cream	Strong Yellow
Sun Tone	Faded gray	Slightly green	Cream	Cream
Deep Cream	Bluish	Intensified	Slightly grayed	Yellowish
Governor's Red	Slightly bluish	Yellowish	Warmer	Yellowish
Deep Blue	Vivid	Richer	Vivid	Grayed
Dusty Rose	Bluish	Yellowish	Vivid	Yellowish
Deep Yellow	Gray	Vivid	Vivid	Redish

Source: "How to Use Color in the Shop" American Machinist
May 9, 1946

EXHIBIT 11

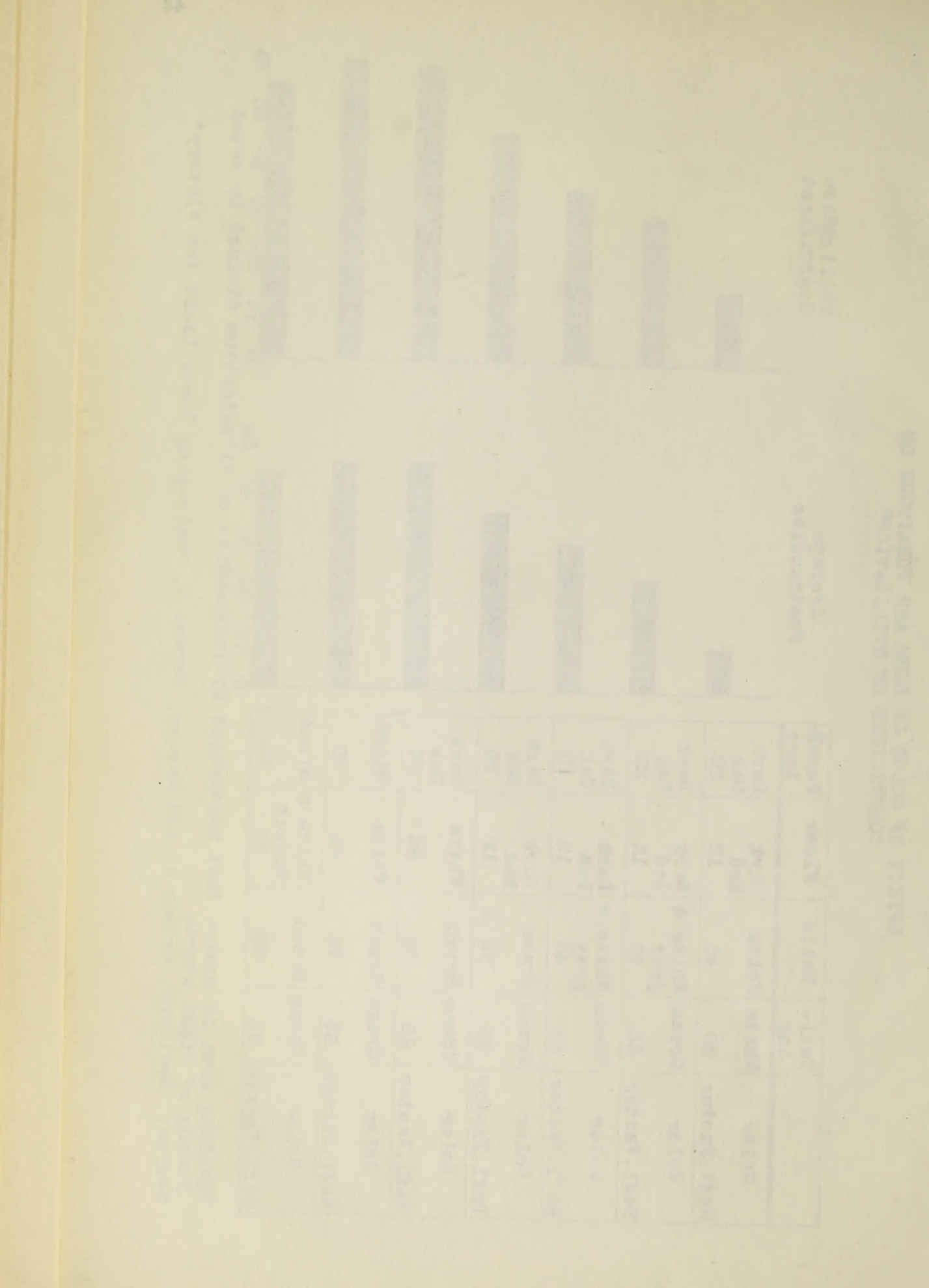
EFFECT OF COLOR OF ROOM AND FURNITURE ON COEFFICIENT OF UTILIZATION*

	Ceiling	Walls	Floor	Furniture
Color	White	White	Dark Red	Dark Oak
Refl.Factor	30	40	12	20
Color	Cream	White & grey	Dark Red	Dark Oak
Refl.Factor	65	40	12	20
Color	Cream	White & grey	Dark Red	Dark Oak
Refl.Factor	85	40	12	20
Color	Cream	Green	Dark Red	Dark Oak
Refl.Factor	85	72	12	20
Color	Cream	Green	White	Dark Oak
Refl.Factor	85	72	85	20
Color	Cream	Green	White	Blond
Refl.Factor	85	72	85	50
Color	Cream	Green	White & Russet	Blond
Refl.Factor	85	72	70	50



*Reading Area in square feet multiplied by footcandles of illumination divided by rated lumens of light source.

Source: Brainerd, Arthur A, and Massey, Robert A. "Salvaging Waste Light for Victory"



CHAPTER III.

COLOR IN INDUSTRIAL SAFETY

I. History of Safety Colors

> "Of all the tools at the command of the Safety Engineer, none is more simple or effective than COLOR."[1]

This or similar statements can be found frequently in any discussion of industrial safety. Color has always been used in one manner or other by safety engineers, but it has only been since about 1943 that any concerted action by safety engineers or industrialists was taken to formulate and put into practice a standard safety color code.

Perhaps the earliest color code to affect safety engineering was the American Standards Association's "Scheme for the Identification of Piping Systems"[2] which is discussed in greater detail later in this chapter. This code had the effect of making safety engineers and industrialists alike stop and think about the benefits of a standard color code for safety. This desire for a standard code was helped along by the formulation in 1941 of "American Standard Specifications for Industrial Accident Prevention Signs"[3]

1. U. S. Gutta Percha Paint Company, "Safety and Equipment Service Color", p. 2.

2. American Standards Association, "Scheme for the Identification of Piping Systems", Code A-13-1928.

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which standardized the size, design, and color used in accident prevention signs for particular types of hazards and in 1942 by a "Building Exits Code"[1], which standardized the color, size, and design, and other factors in the makeup of exit signs.

During the war years, especially, we saw more and more need for a standard color code. While color was frequently used in safety engineering for industry, many of its applications were inconsistent and confusing. A hue such as yellow, for example, or red may be applied in a wide variety of ways and with little regularity or meaning. Obviously, any application of color should hold all possible significance and not merely "wave brightly before the eye". If red is used to indicate fire protection equipment, it should not, at the same time, be used to indicate hazards. One factory may have its machine guards painted red - which would indicate that the very safety devices themselves are dangerous. Yellow as well has been given many widely different applications, some hazardous and some safe. This promiscous use of color is not only confusing - it defeats its very purpose. One can easily imagine what would have happened during the Texas tornado of May 1947 or in the hurricane of 1936 in New England when the telephone and electrical companies rushed workers from all over the country to help repair phone

1. American Standards Association, "Building Exits Code", Eighth Edition, 1946, Code A-9.1-1946.

equipment, power stations and entire systems for cities and plants, if the safety codes were different in all these sections. Much time would be lost in needless training and inquiry as to what that color or this color meant and no doubt there would have been many accidents caused by this confused use of color.

Color in a safety program should attract the worker's attention, call forth specific pre-determined associations, and respect previous usage. The association of red with fire protection, and green with safety is traditional. It is for a similar reason that the "Building Exits Code" of the American Standards Association changed the color of exit signs from red to green.[1] Red normally means "stop" and green "go" and therefore it was felt to be inconsistent with traditional usage to have exit signs in red. A practical program must take into consideration the commonly recognized colors, each of which can be readily identified by name.

When a color code is adopted in a plant the worker quickly learns the meaning of these colors and symbols. His reaction to any emergency becomes spontaneous. As he moves from one building to another, he knows that the color signals that he sees in one place indicate the same things elsewhere. This is good safety practice and any color code that

1. American Standards Association, op. cit., Code A-9,1-1946, page 53, section 1205 and 1206.

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II. Marking Physical Hazards

A. DuPont Safety Color Code

Therefore, in 1944 at the request of the War Department the American Standards Association proceeded to form a committee from industry and government to establish a uniform safety color code. Meanwhile many of the leading manufacturers of paint, seeing the need for such a code, proceeded to do independent work along similar lines. The Finishes Division of the E. I. DuPont de Nemours and Company announced one of the first complete safety color codes at the 15th Annual Safety Convention, Greater New York Safety Council, on March 28, 1944. This code made use of six colors, as listed below.[1,2]

High Visibility Yellow: To mark strike-against, stumbling, falling or tripping hazards. Recommended for use on trucking equipment, protruding parts, curbings, dead-ends, low beams, railings, loading buckets, stairway approaches, floor pan edges, etc.

1. Finishes Division, E. I. DuPont de Nemours & Company, "Safety Color Code", pp. 2-3.
2. See Exhibit 12, page 50 for illustrations of several examples of this code.

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2. See Exhibit 12, page 50 for illustrations of several examples of this code.

Alert Orange: To mark portions of machines or equipment that might cut, crush, electrocute or otherwise injure a worker. Use on such items as the interior surfaces of fuse boxes, machinery guards, exposed parts such as pulleys, gears or cutting devices.

Safety Green: To mark first-aid equipment. Use on such items as dispensaries, medicine cabinets, stretchers, gas mask containers, respirator containers, surgical wagons, etc.

Fire Protection Red: To mark instruments for combating fire. Used on such items as extinguishers, fire hoses, fire hose connections, hydrants, apparatus, fire blankets, fire pails, alarm stations, etc.

Precaution Blue: To mark electrical controls and equipment under repair. Use on ovens, vats, electrical controls, boilers, valves stems, dryers, tanks, compressors, scaffolding, etc.

Traffic White (Grey or Black)[1] To mark facilities for good housekeeping. Use on aisle markings, corners, waste receptacles, floor areas immediately surrounding waste receptacles, etc.

B. American Standards Association Safety Color Code

In July 1945 the American Standards Association

1. DuPont engineers recognized the fact that under some conditions white would not be practical on floors, stairs and containers and therefore set aside grey and black to be used for traffic and housekeeping markings when white cannot be used.

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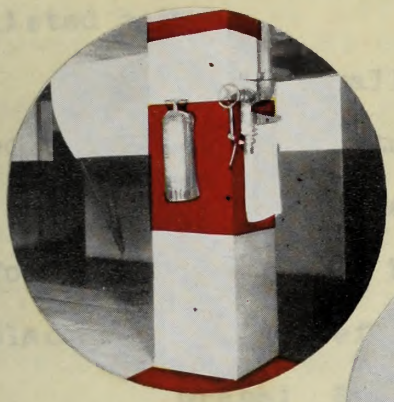
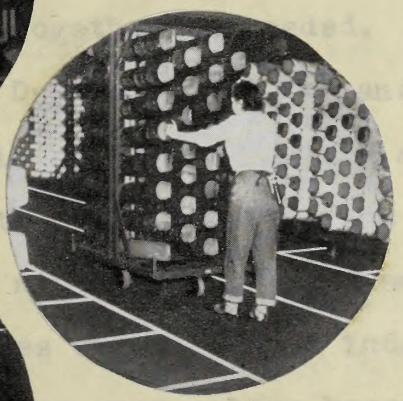
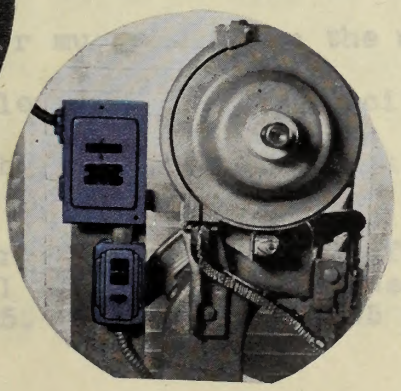
EXHIBIT 12

APPLICATIONS OF DUPONT SAFETY COLOR CODE







Fire Protection Red

Safety Green

High Visibility Yellow

Traffic White

Alert Orange

Precaution Blue

EXHIBIT 12

APPLICATIONS OF DEPONT SAFETY COLOR CODE

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eful to give their personnel

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Red: Shall be used to identify (a) Fire Protection equipment and apparatus, (b) Danger, (c) Stop.

Yellow: Shall be used to designate caution and for marking physical hazards. Yellow may be striped with black for greater effect.

Green: Shall be used to designate safety and identify all safety equipment. Green may be striped with white for greater effect.

Black, White: Shall be used to designate traffic markings and for housekeeping. The colors may be used separately or striped together as needed.

Both the DuPont Color Code and that of the American Standards Association have been widely accepted. It would seem that perhaps the DuPont Code gives the industrialist or safety engineer more latitude and the ability of covering the different classes of hazards in industry more carefully. On the other hand, too many colors become confusing. The fewer colors a worker must remember the more effective it is likely to be as long as this simplicity does not lead to confusion. The biggest complaint against the American

1. American Standards Association, "Safety Color Code for Marking Physical Hazards and the Identification of Certain Equipment", 1945. Code Z-53.1-1945 pages 5-7.

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1. American Standards Association, "Safety Color Code for Marking Physical Hazards and the Identification of Certain Equipment", 1945. Code Z-53.1-1945 pages 5-7.

Standards Association Code is that the color red is used far too many things. Ordinarily it is not good practice to have red indicating fire equipment also danger or hazard. However, one cannot on the other hand develop a system for use in a plant that goes contrary to what the worker will face outside the plant. Red has always indicated danger and as such the worker faces it many times to and from work. It does not seem advisable to make a change that is effective just in the plant. Such a change will only lead to confusion in times of emergency when the worker is acting by habit and training. From the wording of the American Standard Code it can be seen that they are not trying to use red for all danger or hazard but only for those which the worker will face constantly outside the plant and which if changed might cause more confusion than that which exists at the present under such an arrangement. Thus the American Standards Code omits the use of Alert Orange used in the DuPont Code to show danger.

The only other difference between the two codes is that of Precaution Blue which is omitted by the American Standards Code. This color is used to prevent operation by unauthorized persons. Thus a worker repairing a section of electrical wiring would hang a blue tag on the shut-off switch to prevent anyone from turning power into the line while he was working on it. Also, in the second case tags of blue would be attached (or painted on) to valves and

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controls to make the worker stop and think to be sure he has complied with all the requirements before he uses the valve or control. It is not a hazard nor is it dangerous but is merely an extra precaution. The American Standards Code refers the reader to another standard on accident prevention signs for coloring and wording of tags and signs rather than using the color blue in its Safety Color Code.[1]

C. Value of Safety Color Codes

Color speaks a universal language to the mind through the eye. The relatively high frequency of color blindness must also be considered in developing any system using color and more especially in a safety color code. That is one reason why the number of colors must be limited, and why the hues must be sharp and easily differentiated in any kind of illumination. In most cases while the color-blind person will not see the same color as the person who is not color blind there will be a difference between the colors he sees. To further aid in the differentiation of the colors by color blind people we may add symbols. That is, the color is always painted in the same pattern. Also, by the very fact that we are standardizing the application of colors will help the color blind to recognize the shades they see for what they are.

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The value of a safety color code has been recognized by leading industrialists because it provides a coordinated standard of practice for any plant in any industry. Its consistent application lowers accident rates, reduces man-hours lost through absenteeism and improves moral. Higher standards of operating efficiency are the results.

In late 1944 the Richmond Army Depot adopted a safety color code with the following results:

1. Small four wheel trailers, painted a dull black, had been a constant source of accidents, 16 per month on an average, caused either from tripping over them or actually bumping into them while they were in motion. These accidents were generally blamed on the inability of the worker to see the trailers in the aisles. As a result of the color code these trailers were striped yellow and black. Up until 1946 not a single accident had been reported from this cause.

2. All traffic lanes were painted white and the corners of all stacked materials were protected by corner boards painted a highly visible yellow, upon which is a diagonal black stripe. Immediately a decrease was seen from damage due to handling trucks hitting piled material in turning and running down aisles. Also, the fact that

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it was easier to store materials without danger of getting them out too far in previously unmarked traffic lanes.

3. Guy wires supporting power line poles were constantly being hit by trucks and personnel. Guards painted yellow and black were placed on the wires. From 1944 to 1946 not a single accident from this cause has occurred.

4. The depot found the greatest results in the use of yellow. With no training whatsoever the almost 3,000 employees of the Richmond Depot learned to respect yellow and black stripes and plain yellow as designating a hazard.[1]

As a result of the work with color at the Richmond Army Depot and many others, the Provost Marshal General of the Army advocated the use of a standard color code in all Army depots.[2] One depot reported that during the first year after adoption of the code, that for each 1,000,000 man hours worked disabling injuries were cut from 13.25 to 6.99.[3]

The DuPont Finishes Division claims that many of the Army Depots were able to eliminate certain accidents entirely and that certain other accidents have been reduced from a frequency of 46.14 per year before the use of the

1. Industrial Standardization, July 1946, p. 165.
2. "National Safety Color Standards Recommended for Industrial Use", Distribution Age, September 1945, p. 52.
3. E. I. DuPont de Nemours, "Color Conditioning for Industry", 1946, p. 21.

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color code to only 5.58 per year after use of the color code.[1]

A recent article in Popular Science states:

> Accident rates in newly color-conditioned plants usually take a sharp drop and stay down. Typical drops reported range from 20% (Tulsa Boiler and Machinery Co.) to 40% (Bliss and Laughlin, Inc.)[2]

D. Safety Color Conditioning

Another phase of safety color engineering is the painting of machinery in "three dimensional" color and to the color-conditioning of walls, ceilings and floor for better visibility. The better light and visibility that the worker has, the less accidents he is apt to have. This phase of color engineering has already been discussed in detail but it is mentioned here simply to recall to mind that one of the chief causes of accidents is poor illumination and poor differentiation between moving and non-moving objects. General all around color conditioning of a plant is therefore a great aid to better accident prevention.

Another factor of color conditioning in industrial safety is that of good housekeeping. Keeping the factory clean and in ship shape order is a hard job. Color, properly used can be a great aid in this effort. Waste cans are painted in colors to designate the type of material to throw into them and also to stand out from their surroundings; thus reminding the workers to throw the waste

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there. Color can also be used to call the worker's attention to where things go on his bench thus assuring that everything is always put back in its proper place. Corners of rooms, stairway landings and wells are kept cleaner if they are painted white because the worker is restrained from spitting and throwing things where they stand out so prominently. This also applies to putting a white circle beneath refuse cans. This simple device keeps people from missing the can or container.

The Carrol Dunham Smith Pharmical Company of New-Brunswick, New Jersey, had trouble keeping some items of fire protection equipment in their proper places around the plant. Workers would borrow them for other uses and they would not be missed until they were needed or until one of the periodic inspections discovered the fact that items were missing. In an effort to help relieve this situation all wall areas upon which fire equipment was placed was painted red. Contrasting bright yellow silhouettes of all the equipment to be placed on this wall were then painted on the red background. When the equipment was in its proper place the yellow did not show. However, as soon as a piece was removed it was immediately evidenced and supervision could take quick action to see that the peice was returned or replaced. It was also found that the workers had less complusion to remove the items when the glaring yellow struck them in the eye. Misplacement and borrowing of fire

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> From our observations to date it is clear that "Color Dynamics" has helped to make our plant a cleaner, more attractive, more efficient, and safer place in which to work.[2]

Mr. Bolton Sullivan, President of Skilsaw, Inc., Chicago, Illinois also feels that color conditioning has reduced accidents in his plant when he said in a recent magazine article,

> Use of focal and eye rest colors permits the worker to see his job better. Eye fatigue is lessened and accident hazards are reduced.[3]

In concluding this section on the application of color to the marking of physical hazards it seems appropriate and important to state that color is not the solution to the elimination of all accident problems, it is a help and has never been intended by an advocate of its use that it be considered in any way a substitute for the adequate guarding

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III. Safety Color Codes for Piping Identification

A. History and Need for Piping Code

Perhaps one of the earliest applications of color to industrial activity, other than as an auxiliary factor or aid to illumination, is that of applying color to a scheme of identification for piping systems. The first reference we find to this use dates back to 1908 when Mr. William H. Bryan of St. Louis presented a comprehensive article on the "Identification of Power House Piping by Colors" before the American Society of Mechanical Engineers. (A.S.M.E. Proceedings, Vol. 30, pp. 773-782). Great interest was shown in this paper and consequently we find that similar systems were placed in use by other companies using pipes to transport materials. The American Society of Mechanical Engineers organized a committee to study the Bryan paper and its associated problems. The subsequent report by the committee[1] stressed the value of identification of power house piping by colors and recommended it for use.

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U.S. Navy Bureau of Engineering in 1917 and the Bureau of Docks in 1919 placed a system of identification of piping by color in use aboard ships and land stations. Generally speaking the systems used by all these various companies and the government were effective solely for their own particular set-ups. The codes used suffered mainly from a lack of uniformity and particularly because there was no universal differentiation between safe and dangerous materials. As a result of these conditions, spontaneity of action in time of emergency was lost, particularly when outside agencies, such as fire departments, were called in to assist. This lack of uniformity also showed up in the transfer of men between plants within a company where different systems were in use. Much confusion resulted and no doubt caused accidents and lost time.

B. American Standards Association Piping Code

In 1928 the American Standards Association established a committee sponsored by the National Safety Council and the American Society of Mechanical Engineers to study the problem and to develop a standard color system that could be used by all industries and which would particularly differentiate between safe and unsafe materials. The committee was made up of representatives from interested associations, government and industry. The committee studied all the exiting papers and reports and sent out numerous

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questionnaires to find out as much as possible about the systems in use. From this they assembled the material which is presented in "Scheme for the Identification of Piping Systems".[1]

The committee found that the principal requirements for a standard system were: 1. Distinguishability, 2. Flexibility, 3. Inclusiveness, 4. Simplicity, 5. Practicability, and 6. Rationality. The code developed meets as many of these requirements as the present state of the art will permit. The code does not make use of many colors;in fact,it does not consider the multi-color systems in use to be too effective. The American Standards Association Committee found that there are very few colors that can be applied and still show sufficient difference to be readily recognized under adverse conditions. Another limiting fact was that many color pigments would not stand up or hold their hue under the use and conditions where they would be applied. It was, therefore, necessary to limit the use of main colors to five classes of materials which the committee felt could be differentiated from each other. The five classes and their distinguishing colors are listed below.

Class (2)	Color
Fire Protection	Red
Dangerous Materials	Yellow (or Orange)
Safe Materials	Green
Protective Materials	Bright Blue
Extra Valuable Materials	Deep Purple

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Realizing that such a limited system would not fulfill all the demands that a user would require, the committee went further and suggested that in order to actually name the material in the pipes, a second color be added to the main color as a stripe beside or upon it.[1] The five main colors would lose their identity as listed above when used as secondary stripes.

In applying the colors to the pipes it is recommended by the Code and also by an article appearing in the American Machinist for May 9, 1946 form which the following is quoted,

> In this practical method of identifying pipe lines, it is recommended that the piping be painted to match the surrounding areas and that only couplings, unions, valves, or bands in identifying colors be used. This saves in maintenance costs and eliminates the possibility of bright colored pipes lending a guady circus effect to the interior of the plant.[2]

C. How to Apply Piping Code

The following plan is recommended by the American Standards Association for the application of a system of color codes to piping in a particular plant.

1. List all the materials carried in the pipes of the system or systems.

2. Assign each of these materials to one of the

1. For an example of such a color code as applied to piping of paper and pulp mills, see exhibit 13 page 66 .

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3. Froup the materials assigned to each class for the purpose of facilitating the selection of sub-class markings.

4. Choose between the alternative methods of (a) color bands or (b) complete color painting.

5. Assign a legend or color stripe to each material listed under each of the five main classifications.

6. Refer to Appendix C of the Association's "Scheme for the Identification of Piping Systems" for the color pigment to be assigned the five classes and subclasses. (See 2nd paragraph immediately following for further explanation of this selection of the right pigment).

7. All colors which have a total reflective value too low to permit ready differentiation at minimum illumination should be excluded. Otherwise, any paint or color coating may be used if its dominant hue falls unmistakably within one or the other of the five spectral color regions of the Standard.

8. A test of the effectiveness of the color hue used may be made with an ordinary hand flash light held by an operator at the normal reading distance. If color is

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9. Paint all piping as decided in the above steps.

10. Train all personnel concerned in the color code use.

The E.I. DuPont de Nemours Company, Finishes Division, in a descriptive circular entitled "Piping Identification" lists four reasons for using color and also for only painting portions of the piping systems.

ECONOMY - By painting pipes same as the surrounding areas and only couplings, unions, valves or bands in identifying colors, labor costs is lowered.

APPEARANCE - Painting the major portion of pipes like adjacent areas, avoids the "circus-like effect" that sometimes results from solid pipe identification.

SAFETY TO PERSONNEL - Identification of pipe lines prevents accidents such as "hot-pipe" burns, acid burns, and steam burns. In an emergency prompt identification may be a safety factor of major importance in bringing the difficulty under control.

SAFETY OF MATERIALS - Identification of piping reduces the possibility of loss through use of wrong materials.[1]

In selecting types of pigments and substances to

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Thus we find another important use of color in the industrial life of today. The study of color as applied to piping is interesting because it was one of the first uses of color as such that we can find and also the fact that it has become well accepted as an intergral part of any piping system. Here again color proves its ability to form a simple, fast, easily handled system for identification and proves its worth as one of the vital tools of modern industrial management.

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EXHIBIT 13

IDENTIFICATION OF PIPING SYSTEMS IN PULP AND PAPER MILLS

		Band	Stripes
Steam			
High pressure, (100lbs -up)	Saturated	Orange	White
	Super	Orange	White-gray
Low pressure, (20 to 75lbs)	Saturated	Orange	White-black
	Super	Orange	....
Low pressure, (to 20lbs.)	Saturated	Orange	White-green
	Super	Orange	....
Water			
Fire Protection		Red	....
Fresh		Green	....
Circulating		Green-blue	....
Boiler feed		Green	Black
Blow-off		Green	Brown
Make-up		Green	Gray
Treated		Green	Yellow
Filtered		Green	....
Waste or white water		Green	White
Hot		Green	....
Wash		Green	....
Return Condensate		Green	Black
Hydraulic piping:	High	Yellow	Green-red
	Low	Green	....
High Pressure, 50 to 100lbs.		Yellow	Black-white
Low Pressure,		Green	Black-white
Clay, Alum, Size			
Alum		Buff	....
Size		Green	....
Clay		Gray	White
Color		Green(lt.)	....
Groundwood Pulp			
Grinder Pressure,	water	Green	....
	oil	Yellow	Orange
Slush Stock			
No. 1 grade tailings		Green	Brown(gray)
Low pressure		Green	Maroon(White)
White water, high pressure		Yellow	Maroon(Green)

Note: colors in parenthesis indicate flange painting.

EXHIBIT 13

IDENTIFICATION OF PIPING SYSTEMS
IN PULP AND PAPER MILLS

Steam	Band	Stripes
High pressure, (100lbs -up)	Saturated....Orange Super.....Orange	White White-gray
Low pressure, (20 to 75lbs)	Saturated....Orange Super.....Orange	White-black ....
Low pressure, (to 20lbs.)	Saturated....Orange Super.....Orange	White-green ....

Water		
Fire Protection	Red	....
Fresh	Green	....
Circulating	Green-blue	....
Boiler feed	Green	Black
Blow-off	Green	Brown
Make-up	Green	Gray
Treated	Green	Yellow
Filtered	Green	....
Waste or white water	Green	White
Hot	Green	....
Weak	Green	....
Return Condensate	Green	Black
Hydraulic piping: High	Yellow	Green-red
Low	Green	....
High Pressure, 50 to 100lbs.	Yellow	Black-white
Low Pressure,	Green	Black-white

Clay, Alum, Size		
Alum	Buff	....
Size	Green	....
Clay	Gray	White
Color	Green(lt.)	....

Groundwood Pulp		
Grinder Pressure, water	Green	....
oil	Yellow	Orange
Slush Stock		
No. 1 grade tailings	Green	Brown(gray)
Low pressure	Green	Maroon(White)
White water, high pressure	Yellow	Maroon(Green)

Note: colors in parenthesis indicate flange painting.

	Band	Stripes
Sulphite Pulp		
Gas, lead, or cast iron	Yellow	Purple
Acid, lead, and bronze	Yellow	Purple-red
Blow-off, obvious	Black	....
Waste liquor		
Obvious unless reclaimed	Green	Purple-black
Low pressure	Green	Maroon(white)
White water-high pressure	Yellow	Maroon(green)
Sulphite brown stock	Gray	Brown
Sulphite, unbleached	Gray	....
Sulphite, bleached	Gray	White
Chlorine gas	Yellow	Yellow
Milk of lime	Green	Olive-white
Bleach	Yellow	Yellow-white
Soda Pulp		
Caustic liquor, strong	Yellow	Brown(Red)
Caustic liquor, weak	Yellow	Tan(red)
Carbonate liquor(green)	Green	Brown-white
Strong black liquor	Yellow	Brown-black
Weak black liquor,	Green	Brown-gray
Brown stock	Green	Brown-buff
Unbleached stock	Green	Brown-gray
Bleached stock	Green	Brown-white
Sludge(lime mud)	Green	Olive
Straw Pulp		
Same as Soda Mill		
Sulphate Pulp		
Milk of Lime	Green	Olive
Old Paper		
Bleach Liquor	Yellow	Yellow-white
Soda ash	Green	Brown-red
Defibered stock	Green	Black-gray
Unbleached stock	Green	Green-brown
Bleached stock	Green	Gray-brown
Conversion		
Slush	Green	Gray-tan
Paper stock	Green	Gray-yellow

Note: Colors in parenthesis indicate flange painting.

Sulphite Pulp

	Sand	Stripes
Gas, lead, or cast iron	Yellow	Purple
Acid, lead, and bronze	Yellow	Purple-red
Blow-off, obvious	Black	....
Waste liquor		
Obvious unless neutralized	Green	Purple-black
Low pressure	Green	Maroon(white)
White water-high pressure	Yellow	Maroon(green)
Sulphite brown stock	Gray	Brown
Sulphite, unbleached	Gray	....
Sulphite, bleached	Gray	White
Chlorine gas	Yellow	Yellow
Milk of lime	Green	Olive-white
Bleach	Yellow	Yellow-white

Soda Pulp

Caustic liquor, strong	Yellow	Brown(Red)
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Carbonate liquor(green)	Green	Brown-white
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Sludge(lime mud)	Green	Olive

Straw Pulp

Same as Soda Mill

Sulphate Pulp

Milk of lime	Green	Olive

Old Paper

Bleach liquor	Yellow	Yellow-white
Soda ash	Green	Brown-red
Deltered stock	Green	Black-gray
Unbleached stock	Green	Green-brown
Bleached stock	Green	Gray-brown

Conversion

Slush	Green	Gray-tan
Paper stock	Green	Gray-yellow

Note: Colors in parenthesis indicate flange painting.

	Band	Stripes
White water	Green	Green-white
Couch pit stock	Green	Green-white
Broke stock	Green	Green-white

Key to Band Classification

Fire Protection	Red
Dangerous	Yellow
Safe	Green
Protective	Blue
Extra Valuable	Purple

Source: American Standards Association
"Scheme for the Identification of
Piping Systems"

	Band	Stripes
White water	Green	Green-white
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CHAPTER IV

COLOR IN MAINTENANCE

I. Lubrication of Machinery and Equipment

A. History and Need for Color Code.

The proper lubrication of production machinery and equipment has always been an important problem. In early days when machines were of simple design and operated at low speeds, maintenance was merely a matter of lubricating the machinery at certain intervals. Maintenance was also simplified by the fact that the science and development of the various types and grades of oil for general and special applications that we know today was then relatively undeveloped. In most plants only a few types of oil were in use and the three R's - right place, right oil and the right way - of lubrication were not considered too strongly. However, as our plants grew and machines became more complicated, closer tolerances and greater speeds demanded better oiling and more important, demanded the use of a wide variety of general and special purpose oils. As each new oil or lubricant was added to the maintenance list and as the need for correct and timely lubrication for all machines became evident, the problem of how to establish and maintain a system that could be easily understood and yet be foolproof took on greater significance. Professor Charles A. Koepke

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of the University of Minnesota makes the statement that about 90% of the oils used in maintenance was wasted due to using the wrong oils in the wrong places and to poor systems of lubrication control.[1]

Professor Koepke further states,

> Keeping the various oils in their proper drums, oil cans, and bearings becomes a major problem unless some system is adopted to aid identification.[2]

Professor Koepke has not been the only one to state the problem of the lubrication maintenance men. In 1942, the American Standards Association was asked to develop a Standards Color Code for the lubrication of machinery. The need for such a study is well stated in the forward of the approved code:

> The reason for this request was the serious damage to machine tools and other machinery being caused by the misapplication of given lubricants to lubrication points for which they were not intended, due to lack of proper identification of the contents of the cans or other lubricating devices. It was held that such damage, and the consequent impairment of the war effort, could be avoided, if some guide were established to facilitate the correct application of each lubricant.[3]

1. Koepke, Charles A., Plant Production Control, 1941, p. 215.

2. Ibid, 1941, p. 215.

3. American Standards Association, "Color Code for Lubrication of Machinery", 1945, p. 3.

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This need for a standard system of lubrication color coding was also felt by many oil companies in the country. One such company, Standard Oil Company of Indiana, in offering an identification system makes the following statement:

> Today, as never before, management and production executives, engineers, machinery builders and operators alike are aware of the vital role of lubrication. It is one thing to build and equip a plant and quite another thing to keep it running smoothly and efficiently. It is to meet this very situation that Standard Coded Lubrication Service has been developed. [1]

II. Color Codes for Machinery Lubrication

Thus we can readily see the necessity for developing a code or system which would coordinate all the various factors of lubrication and still be foolproof. In a study of such systems we find that color is playing an important part. Lubrication engineers, and management and production executives realize the value of this simple, easily understood aid.

A. Basic Code

The use of color for lubrication basically follows the plan outlined below:

All lubricants used in a plant are given a different color which distinguishes it from all others used.

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The basic application of color to lubrication has been modified by various users to allow greater versatility and adoption. Some of the more interesting and effective modifications and results are as follows:

a. Fairchild Camera and Instrument Corporation, Jamaica, New York stated that it found the use of color to be very helpful and that the workers found the work of lubrication to be easier and quicker. The modifcation that Fairchild added was the use of colored arrows to indicate lubrication points not easily seen on the machines.[1]

b. Mr. R. J. MacMullan has added to the basic system a further use of color to show frequency of oiling. The indicator on the lubrication point is made of two colors; an outer circle and an inner circle or bullseye. The outer circle would indicate the type of lubricant and

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correspond to the color on the container. The inner circle or bullseye would indicate the frequency of oiling. Thus, the oiler would know from looking at the indicator not only the type of oil to use but whether or not to oil it at that time. This dot could also indicate by its color whether it was to be constantly oiled by the operator.[1] For an example of such a color code see Exhibit 14, on page 81 .

c. Standard Oil Company of Indiana uses only two colors in its lubrication system. It feels that colors are confusing if too many oils are needed and that colors are apt to appear different under different lighting conditions. Therefore, they use a number for each type of oil or grease and use two colors, red on yellow and blue on yellow to show greases from oils, or operator lubricated points from maintenance crew lubricated points or to indicate different lubrication intervals. It is also necessary to use the two colors in this system to readily indicate the lubrication point and to serve as a background for the number of the lubricant. While it would seem that the numbers would aid in plants using large variety of oils and greases, the process of selecting the right container would be more difficult and some of the effectiveness of a

1. MacMullen, R. J., "Colors Tell Which Oil, When", Factory Management and Maintenance, February 1939, p. 79.

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color code would be lost.[1]

B. American Standards Association Color Code for Machinery.

The American Standards Association in its "Color Code for Lubrication of Machinery" uses both colors and numbers. The colors are used to indicate five general classes of oil and three general classes of grease. (See Exhibit 15, page 72). Where a company is using more than one kind of lubricant belonging to the same general class then numbers will be used in conjunction with the regular color. The code also suggests that where the lubrication color will not stand out against the color of the object upon which it is placed, a light grey background of sufficient area to allow the color to stand out be placed on the object first and then apply the lubricant color either as paint or decalcomanias.

C. Advantages Obtained from Using a Machinery Color Code.

Color, properly used and understood, can and does play an important role in the lubrication of machinery and equipment. It offers to management the following advantages not readily obtained from any other system:

a. Gets the right lubricant into the right places.

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b. Helps to conserve equipment by reducing the possibilities of misapplying lubricants and thus incurring damage to vital frictional parts.

c. Simplifies the work of the maintenance crews by giving each lubricant a color and using the same color on everything connected with the use and application of that lubricant.

d. Oilers need not learn the brand names and grades of lubricants. They merely follow the simple color code.

e. Colors make the lubrication points stand out and help to insure that none will be missed by the oiler.

f. Color codes allow less confusion on the part of the oiler when changes are made in brands and grades as long as the color code is properly applied to the new lubricants.

In spite of fine storage and dispensing equipment available, efficient and labor saving devices, and care taken to secure quality lubricants, the fact still remains that human help is indispensable. This system of color codes for lubrication is planned to minimize, as far as possible, the fallibility of this human factor, and to

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help make foolproof this vital phase of production.

III. Maintenance Scheduling

One of the hardest problems in maintenance work is to keep the schedule always before the department and to be able to know at a glance the status of all the machines and equipment. With such information readily at hand, work can be more efficiently assigned, production control can be immediately informed of machine conditions and replacement policies can be more accurately determined. The Leeds Northrup Company of Philadelphia, Pennsylvania developed a series of charts, making excellent use of color to let its maintenance crews know at all times the status of machines and equipment.

This system called for listing all machines and equipment that the maintenance department were responsible for. Then opposite each machine or piece of equipment was hung a colored card to indicate the condition of the machine. White indicated that the machine was in good condition, blue that the machine was in fair condition, and yellow that it was in poor condition. Red indicated that the item was not available for production and was undergoing emergency or rush repairs while green indicated that the item was not currently in use but was available in the stock rooms.[1]

1. Factory Management and Maintenance, February 1946, pp. 145-184.

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IV. Maintenance of Tools, Jigs, and Fixtures

Another bothersome maintenance problem is the issuance and inventory of tools, jigs and fixtures. The McCaskey Register Company of Alliance, Ohio has developed a very effective system using colored forms. Three colors are used, white, pink and yellow. When an employee draws a tool, jig or fixture, he fills out in triplicate a tool order giving all the necessary information about the item being drawn, and signs his name. The crib attendent adds the tool number to the slips and returns the yellow copy to the workman along with the tool. The workman returns with the tool to his place of work and places the slip in his tool box or on the clip provided at his machine, as a constant reminder that he is responsible for certain tools. The crib attendent files the white original in a clip assigned to the worker. This clip holds all the items that a particular worker is responsible for. The pink ticket is filed on a clip at the tool storage location as a constant reminder that tools are out of the crib and also as a check on who has them and how long. When a worker returns the tool to the crib he will return the yellow slip and receive in return the white one which he will destroy. Only by having a white slip can the tool crib hold the worker responsible for the tool. Thus we have a very efficient

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tool accounting system. Coupled with these three colored forms for tool accounting are two other colored forms to tell the status of the tools in the bins. If a tool is removed from the bin for repair a green ticket is placed in the bin rack, and if removed for replacement a blue ticket is placed in the bin rack. Thus a crib attendent may very easily take inventory and know exactly what the status of the tools is at a glance. He knows by counting the colored tickets, the number out for repair, the number out in the shope in use and the number that are being replaced. The total of these three tags plus the physical count of what is in the crib should show a total of the number he is charged with on the inventory.

V. Miscellaneous Uses of Color in Maintenance

A. Controlling "On the Line" Maintenance Work.

Keeping machines on the production floor running constantly in order to keep idle time due to minor breakdowns at a minimum is a problem requiring a great deal of coordinated scheduling and a careful record of all maintenance work. However, color can aid in cutting down idle machine time from production line breakdowns even beyond that accomplished by good maintenance scheduling and dispatching.

One very successful use of color along these lines is that used by the J. D. Adams Manufacturing Company of Indianapolis, Indiana.[1] The Adams Company employed a crew of forty maintenance men who were controlled from the central maintenance office. The normal procedure when a machine broke down on the production line was for the foreman to call the central office and report the breakdown. The central office immediately checked its file and dispatched a man to the machine. Many times the foreman did not know what was wrong and the maintenance man had to first inspect the machine and if it was something special would have to return for the necessary special tools and equipment. Many times it was some minor adjustment that only took a few minutes to repair, and yet it may have been that several hours were lost in getting a maintenance man to the machine.

Now all maintenance men at J. D. Adams Company wear brilliant red baseball caps. They can be spotted anywhere in the plant. When a machine fails on the production line the worker or foreman gets the nearest maintenance man, easily located by his bright red hat and have him look the machine over. If it is something that will take the man too long away from his other job or something he cannot fix immediately, he can quickly give the foreman

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the pertinent information about the breakdown so that the central maintenance dispatcher has a better idea of the difficulty and can send a man better prepared to do the job. The time lost by the maintenance men out in the shop from their assigned jobs was not great and it was more than paid for in the saving from the decreased idle machine time. Mr. P. C. Yoke, Plant Engineer of the Adams Company summed up the advantages gained from this simple use of red baseball hats as follows:

1. Built up morale among maintenance men.
2. Cut down repair time as men could be gotten to machines more quickly and better prepared to do the job.
3. Cut down non-operating times on machines as they were more quickly repaired and returned to service.

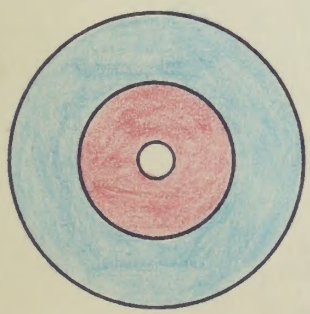
EXHIBIT 14

EXAMPLES OF LUBRICATION COLOR SYMBOLS
FOR MACHINE APPLICATION

Outer Circle: Gear Oil
Inner Circle: Weekly lubrication

Outer Circle: General Purpose Oil
Inner Circle: Daily lubrication

Outer Circle: Anti-Friction Bearing Grease
Inner Circle: Monthly lubrication



Outer Circle: General Purpose Grease
Inner Circle: Operator lubrication (as needed during work)

Source: Koepke, Charles A.,"Plant Production Control" pp. 215
MacMullen, R. J., "Colors Tell Which Oil, When" February, 1939, pp.79-80

EXHIBIT 15

IDENTIFICATION COLORS FOR CLASSES OF LUBRICANTS*

Oil or Grease	Class of Lubricant	Identification Color	Munsell Color Notation
Oil	General Purpose Oils	Brown	YR-4/8
Oil	Machine Tool Spindle Oils	Yellow Green	GY-7/10
Oil	Gear Oils	Purple	P-6/8
Oil	Hydraulic Oils	Yellow	Y-8/10
Oil	Special Purpose Oils	Red	R-5/10
Grease	General Purpose Greases	Light Blue	B-7/6
Grease	Anti-Friction Bearing Greases	Orange	YR-7/10
Grease	Special Purpose Greases	Pink	RP-7/8

*If necessary, put the class identification color mark on a light-gray background

Source: American Standards Association, "Color Code for the Lubrication of Machinery"

CHAPTER V

COLOR IN STORES AND MATERIAL HANDLING

I. Inventory Records

Color also aids the inventory clerk. By establishing a color code to differentiate between the many various classes of materials handled, inventory cards can be handled quicker and greater ease of operation and control is obtained.[1] One company uses buff cards for raw material, salmon cards for purchased parts and green cards for manufactured parts. Another uses buff for standard commercial parts, salmon for raw materials and light blue for consigned material.[2]

Remington Rand Company, Inc. manufacturers of Kardex systems have developed a system of signaling called Graph-A-Matic. A typical Graphic-A-Matic system for control of ordering stores, installed by Remington Rand Inc. in such companies as DeVilbiss Company and the Hughes Tool Company would be set up as follows.

A standard Kardex file is established for each item in the stores room. This card is attached in its container at the top and the bottom one-half inch is visible at all times. The right lower section of this visible

1. Alford, L. P and Bangs, J. R., Editors, "Production Handbook", 1946, p. 375.

2. Ibid, p. 379.

CHAPTER V

COLOR IN STORES AND MATERIAL HANDLING

I. Inventory Records

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one-half inch has a slit in it allowing a numbered card placed in back to show through. This numbered card is divided in the middle by a heavy black line,i.e. the ordering point. To the right of the lines indicates safe quantities, with the highest number representing the maximum inventory. To the left of the line indicates low stock and dangerous conditions, with the lowest number representing the minimum inventory.

The Graphic-A-Matic signal is generally red in color and slides across the bottom of the card. As the inventory clerk issues material he moves the signal to the left. When the signal reaches the black line, the clerk removes from a pocket at the top of the card a requisition form and sends it to the purchasing department to reorder.[1,2]

Thus the stores clerk can tell merely by looking at the visible one-half inch of each card the supply on hand of that item. To make the system even more efficient the following things may be added.

1. In order to have the slip show larger quantities for which there is not sufficient physical room to print the numbers, we can have the numbered cards in colors, thus buff indicates numbers as they are written, pink indicates written numbers multiplied by 10, and blue cards indicate written numbers multiplied by 100.[3]

1. Alford, L. P. and Bangs, J.R., op.cit., pp 385-384.
2. "Teeth for Biting the Earth", Systems, Oct. 1947, pp. 19-21.
3. Ibid, p. 20.

2. Small colored tab is placed on card in position on the left side of the visible inch, which is a 30 day date scale, to show the delivery date of the ordered material and at the same time to indicate an order has been placed.[1]

Similar Graph-A-Matic systems may be established for handling all phases of material control such as:

1. Control of materials for production orders or contracts. Used by Fairchild Aircraft Corporation.[2]

2. Control of Manufactured parts.[3]

3. Control of finished parts. Used by Republic Aviation Corporation.[4]

Other uses could be listed applying similar principles but the important fact here is that the visual card file is made far more effective by the use of colored signals which tell the story at a glance. Mr. E. J. Flynn, Sectional Supervisor, Production Control, of Republic Aviation Corporation, verifies this fact in an article in "Systems" wherein he states:

1. Systems, op. cit., pp 20-21.
2. Alford, L. P. and Bangs, J. R., op. cit., p. 379.
3. Ibid, pages 384-385.
4. "Systems", Vol. 8, No. 7, July 1945, pp. 17-19, 22.

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> We are able by the use of the Graphic-A-Matic control signals to see at a glance the stock position of the thousands of components of the P-47.[1]

II. Material Storage

Color can be of great use in the storage of many items. For example, it is extremely hard to tell the difference between the various types and alloys of bars, sheets or billets of steel under ordinary conditions but when they are rusted it is virtually impossible to do so. For this reason the Earle M. Jorgensen Company, a manufacturer and distributor of steel bars and billets, recommends the use of the color code shown in Exhibit 16 , page 94 , for the handling and storage of this type of material. The ends of the bars, billets, or sheets are identified by this color code and no matter what the condition of the bar, billet or sheet, it can always be readily identified. This procedure is also recommended in "Industrial Organization and Management".[2]

Frequently it is important to keep material being processed for a particular order segregated. This was very true during the period 1941-1946 when governmental priority regulations made it necessary to know exactly what material belonged to what order. Color may be used in several ways to handle this problem. The part may be given a paint job

1. "Systems," Vol,8, No. 7, July 1945, p. 19.
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1. [illegible], Vol. 8, No. 7, July 1945, p. 19.
2. Bethel, Atwater, Smith and Stockman, "Industrial Organization and Management", 1945, p. 274.

or a dab of paint or stamped a color that will identify it from all other parts. A system of colored containers or tote boxes was used to segregate different batches of material. A distinctive colored tag may be fastened to the part or to the container to set it off from other order materials.[1]

To facilitate the location of stored items, the storage rooms and stock cages may be divided up by colors in various major segments or components. Thus a plant making several different products could divide the store rooms up into colored sections, one for each product. When material was requisitioned from the storerooms the clerks by noting the color of the card listing the part would know immediately where it was located in the store room. This system is also of value in handling tools, jigs, and fixtures.

When it is necessary to make use of bulk storage locations in addition to the regular issue cages, color can be used to facilitate the transferring of the material from one to another. Thus each issue bin having material in bulk stores, would have a colored card attached to it. This card would first tell the issue clerk that there was more of the material in bulk stores and would further tell him what store room it was located in.

In metal working shops, a considerable amount of

1. Bethel, Atwater, Smith and Stackman, op. cit., p. 274.

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extra income can be derived by the proper handling and sorting of turnings, filings and scrap. However, to keep the cost of this handling and sorting as low as possible, color can again be put to work. All bins in which the scrap or turnings are stored are either painted distinctive colors or may be designated to hold a particular kind by labeling with a distinctive color plaque. All buckets, or wagons used to collect various kinds of scrap or turnings are painted similar colors corresponding to the kind of metal or alloy they are used for. In some cases the wagons are not painted but the machines using a particular kind of metal are indicated by a colored sign, which allow unskilled help to collect the material easily and with a minimum amount of instruction.[1]

III. Material Movement

Handling material by color is not new. During World War II, color was used in large material handling depots to designate the major war areas and thereby facilitate the sorting of materials to these areas. With each major war area and section assigned a color, it was a simple matter to give inexperienced workers doing rough sorting of supplies the simple information that all material

1. Birren, Faber, "Color for Production," Architectural Forum, July 1942.

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tabbed with a certain color was to be placed in the areas with corresponding color designations. The United States Postal Service makes use of color in handling mail by having airmail letters marked with red and blue strips. Many companies use a system of colored labels to assist the shipping room and internal transportation department to sort materials. One such company has a series of colored labels to indicate to the shipping room the type of transportation to be used. Colored labels are used to indicate to the shipping room that the order is only partially assembled and that additional items will be along shortly.

At freight terminals color is used in sorting out less than carload lot shipments. Colors are assigned to the various trains that load at that particular station. As the material arrives on the platform a colored sticker is placed on the package designating the train that it is to go on by trained experts. It is then a simple matter for the truck operator to convey the article to the proper loading station. It also acts as a constant check during the loading process as an off-color label is readily seen. There is no need for all the help to know every town and station on the route nor does it leave any doubt in the handler's mind as to exactly where the package is to be placed.

Color can be used to indicate types of material being handled so that the workers will know what precautions

to take. This is particularly applicable to packaged goods. The Navy had a system of color markings on all boxes, crates, cartons,and barrels to indicate the general nature of the materials inside. Thus the personnel at the Naval Supply Depots, aboard ship, and on the beach heads knew what to to do with the material and how to handle it merely by the color stencil on it. Both the Army and Navy found that the use of color in this manner was a factor in preventing accidents and mistakes arising from fatigue.[1]

One of the latest suggested uses of color in handling material shipments was advanced by Robert E. Wright, Sr. of Cushmen and Dennison Company in April, 1946. Mr. David J. Witherspoon, Associate Editor of "Distribution Age" carried this idea even further in an article later in September 1946. Both men recognized the expensive, time-consuming business of sorting out packages, crates, and cartons intended for shipment and delivery. When one realizes that in shipping by truck or rail, that a particular package may have to be handled several times and that each time the complete label must be read in order to determine its destination, it is not hard to see how the cost can rise considerably. It was suggested, therefore, that the United States be divided up, geographically, into color zones, regions, districts, and sections. Each designation such as zones would have

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distinctive colors that would distinguish one zone from another. This would be established for the other divisions which could be the same as the zone colors as long as within a particular type of division, colors were different. All packages would bear in addition to the written address, the color code for that address. Possibly colors would be read from left to right, from the largest geographical division to the smallest. It is felt by the two men that such a system if adopted nationally would do much to cut down the cost and time necessary to get material delivered.[1]

Very little has been done along these lines on a national or even local scale except what has been done by individual companies in handling their own particular problems, as previously described.

In plants using conveyor systems where material is of various kinds although of the same physical size, the problem of knowing how to switch the material as it arrives at the central dispatching stations has been a difficult one. In many ways it is like that of handling material for shipping - time consuming and costly to have men examine each package or item closely. One plant, in the greater Boston area, manufacturing shoe boxes instituted a system using colored tags to eliminate the close handling and inspection. Boxes for finished stock were always white tagged and were switched from the conveyor to the stock

1. "Color Zoning for Lower Costs", Distribution Age, Sept. 1946, pp. 46-47.

rooms. Individual customers' orders were given colors that would change from order to order. However, no color would be reassigned to another customer, until the first customer's orders were out of the plant. Each day the conveyor dispatcher would receive notice of the changes and what the new colors assigned represented. Also, the dispatcher received instructions as to how to route and handle the new colors. As the boxes were packed into standard cartons or tied into bundles the correct colored tag was fastened to it by the packer who received the information from the packing slip. The conveyor dispatcher had merely to note the color of the tag on the package as it approached him on the conveyor, check his schedule and push the right button to properly dispatch the material. After the first hour the dispatcher knew the colors and had to do very little referring to the check list.

In shops where all conveyor dispatching is done automatically, color is playing an even greater part. In plants where the materials handled are of different color because of their regular packaging, the job is even easier. As the package moves down the conveyor it passes a battery of electron tubes and photo-electri c cells which are sensitive to the various colors used. Only the color for which it has been set will set the electron tube to operating. As the packages go by this battery of cells they set off

a reaction in one set of tube and photo cells which causes automatic switching of that package to predetermined locations.

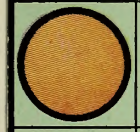
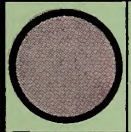
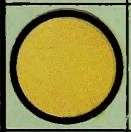
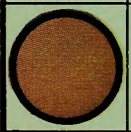
In plants where packages are all of the same color, colored labels or stencils are applied to the packages as they are packed. These labels or stencils will activate the photo-electric cells in the same manner as described above. This action of the photo-electric cell is caused by the fact that different colors have different light reflection values. (See Exhibit 1 , page 10). A photo-electric cell can be made immune to all colors except one. Only when this one color passes is the right amount of light reflected to cause the cell to work.[1]

1. Bethel, Atwater, Smith and Stackman, op. cit., pp. 400-401.

EXHIBIT 16

CARBON AND ALLOY STEEL BARS & BILLETS

When small diameter bars are supplied in an analysis identified by two colors, such as A-4142, one end is painted one color and opposite end other color.

	MILD STEEL		A-2335/40 ANNEALED BARS and UNANN. BILLETS
	C-1019 H.R. FORGING QUALITY BARS and BILLETS, also C.F. and T. & P. BARS		A-3141 ANNEALED BARS and UNANN. BILLETS
	PLOW STEEL (Hot Rolled) B-1112 COLD FINISHED BARS		A-4142 ANNEALED BARS and UNANN. BILLETS
	B-1113 C.F. BARS		A-4142 HEAT TREATED BARS
	C-1040 H.R. FORGING QUALITY BARS and BILLETS AN-QQ-S-684a (4130) HEAT TREATED & C.F. BARS		A-4620 BARS and BILLETS
	AN-QQ-S-684a (4130) ANNEALED BARS and UNANN. BILLETS		A-4815/20 ANNEALED BARS and UNANN. BILLETS
	STRESSPROOF BARS (C.F. also Ground) AN-QQ-S-752a (4140) H.R. ANN. BARS and UNANN. BILLETS		A-8717 BARS and BILLETS
	AN-QQ-S-756a (4340) ANNEALED BARS and UNANN. BILLETS		A-8742 HEAT TREATED BARS
	No. 39 MACHINERY STEEL (Hot Rolled Bars) A-4130 POLISH ROD STEEL (Cold Finished Bars)		A-8742 ANNEALED BARS and UNANN. BILLETS
	C-1019 PRECISION SHAFTING C-1095 H.R. SPRING STEEL		E-52100 SPHEROIDIZED ANNEALED, BEARING QUALITY BARS and BILLETS

Source: Earle M. Jorgensen Company

EXHIBIT 18

Source: Earle M. Jorgensen Company

CHAPTER VI.

COLOR IN PRODUCTION CONTROL

I. Graphic Control

One of the most universal uses of color in production control systems is found in the production control centers where large control boards are maintained. Here the control boards may cover whole walls. Clerks keep the board up-to-date by the use of color. All items on the board tell their story by the color they carry. For example, all rush orders might be indicated by salmon color and all orders behind schedule would be shown in red. One glance at the board tells management the number of rush orders in the plant and the progress they are making. The red tickets immediately tell management that something has gone wrong and where. In fact, the board even may tell why because of the position of the tag, tape and signal. With colors standardized, the board becomes a graphic picture of what is going on. At a glance any order can be picked out and the pertinent facts quickly ascertained. Of course if more detailed information is desired about the particular order then reference is made to the card or tag itself. However, color has immediately placed the important information on an order before management, showing its progress and place in the plant and department for that period.

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A very simple application of color to a card production board makes use of five tickets or cards colored green, yellow, blue, pink, and red. These colors are coded as follows:

Green ticket indicates the first operation to be performed in the plant.

Yellow ticket indicates intermediate operations between the first and last operation performed.

Blue ticket indicates the last operation to be performed.

Pink ticket indicates that the operation is behind schedule and trouble may develop here.

Red ticket indicates serious trouble and that emergency procedures are being taken.

The cards are filled out for each complete cycle of operation for a given item and placed in position on the control board beneath the days required to do the work and opposite the operation name. The cards are turned over so that the blank side shows as soon as the production starting day is reached as indicated by the first green card. A movable date line is positioned on the board each day. All cards or tickets to the left indicate work not up to schedule. All cards to the right indicate work still to be done but on schedule. If the cards are removed from the right of the date line it indicates that the operation

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is ahead of schedule. Pink and red tickets are placed on the board whenever the delay indicates trouble (pink ticket) and to indicate emergency treatment (red ticket). Production personnel can tell at a glance from the colors of the tickets and their position the status of work in the plant and what is being done about it. The board provides an immediate answer to practically any question asked as to progress of production.[1]

II. Tape or String Board

Another type of production control board used in industry today is the tape or string board. This production control mechanism is well described in the Production Handbook from which the following information was taken. (For the mechanics of using this mechanism, pages 203 to 204 of the Handbook should be consulted).

> Signal pegs are available in twelve contrasting colors, each in four shapes and any signal peg may be provided with numbers or identifying symbols as indicated by the application of the particular installation.
>
> By the use of colored vertical cords, automatic control elements may be introduced. The relationship between these vertical cords and the signal and tape pegs indicates at a glance whether work is behind or ahead of schedule and by how much in terms of whatever divisions have been set up by the heading strip.[2,3]

1. Alford, L. P., Editor, "Production Handbook", 1946, pp. 192-197.
2. Ibid, pp. 203-204
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1. Alford, L. P., Editor, "Production Handbook", 1948, pp. 192-197.

2. Ibid, pp. 202-204

3. Bethel, Atwater, Smith and Stackman, "Industrial Organization and Management", 1948, p. 548.

It is the author's firm belief that hardly a single plant could be found where some application of color has not been made in control production through charts and boards.

In a "Graphic Production Control", by C. E. Knoepple, published in 1920, the searcher for information on using color in all kinds of production control problems will find one of the best sources. Knoepple believed that the more one could establish a problem so that the eye could gather in the information, the easier it would be to solve and also the easier one could make use of the many various control devices that he describes. On page 235 beneath the statement, "Colors can be used to advantage in using time cards", he lists seven colors to distinguish time cards one from another. (See Exhibit 17, page 100). He follows this list with the statement,

> As can be readily seen, these distinguishing colors are a form of graphic presentation, for a glance at a dispatcher's board will show the exact condition of the shop.[1]

In discussing the control boards and its mechanism, Knoepple says,

> By letting white indicate the work to be done; green the material ready for work, and black, the accomplishment, we have, in addition to furnishing a graphic presentation, facilitated the task of comprehending the real significance of the showing.

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1. Knoepple, C. E., "Graphic Production Control", 1920, p. 235.

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1. See Exhibit 18, page 101 for colors used by Knoepple for these signals.

2. Knoepple, C. E., op. cit. pp. 272-274.

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By using colored signals (buttons or sliders) to designate irregular conditions, the presentation becomes doubly valuable.[2]

1. See Exhibit 19, page 10 for colors used by Knoepple for these signals.

2. Knoepple, O. E., op. cit. pp. 272-274.

EXHIBIT 17

TIME CARD COLOR CODE

Direct labor - Day work

Direct labor - Piece work

Indirect labor

Idle time--Paid for

Idle time--Equipment

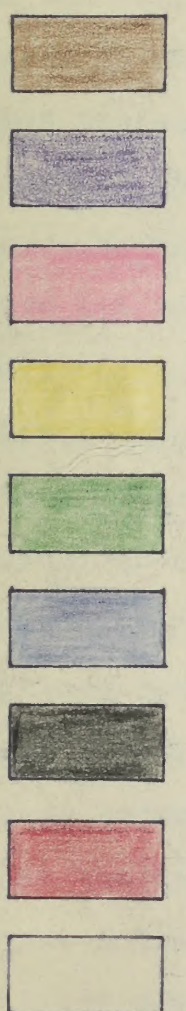
Bonus report

Absent

Source: Knoepple, C. E., "Graphic Production Control"

EXHIBIT 18

TYPICAL COLOR CODE FOR USE IN MACHINE CONTROL



Slow operator

No operator

Machine down for repairs

No tools

No material or material running low

No work or work running low

Behind schedule

Rejections

Memo

Source: Knoepple, C. E., "Graphic Production Control"

CHAPTER VII

COLOR IN QUALITY CONTROL

I. Color Systems to Notify Worker of Inspection Results

One of the criteria of a good quality control system is how promptly the worker is informed of the quality of the work he is turning out and how immediate the notice is to actual performance. The sooner the worker is informed that his quality is off standard after it is discovered the better. Sylvania Electric Products, Inc. of Ipswich, Massachusetts recognized the advantages of letting the worker know his quality constantly but at the same time did not want that notice to distract him from his work by public address announcements nor did they want the detail of getting the written or spoken word to him. For a solution, they turned to color.[1] Electric light bulbs in three colors were placed in strategic locations in the manufacturing locations feeding specific inspection stations. These bulbs were lighted at specific intervals to indicate the quality being turned out by those sections. A red bulb indicated that the department was off standard. A yellow bulb indicated that the department was pushing the danger limits. A green bulb indicated that the department was within standard and turning out acceptable work.

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1. "Factory Management and Maintenance", Vol. 103, Sept. 1945, pp. 116 and 120.

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color give the quality control department quicker control over the type of work being turned out, but it also proved to offer a certain amount of non-financial incentive to the workers. Soon there was a spirit of friendly competition between the various departments to see who could keep the green light burning longest and to keep the red light from showing in their department. To take further advantages of this spirit the quality control department had a large chart placed in the plant where all the workers could see it. The chart was ruled off to show a month's operations. Each department was listed and its record kept with red, green, and yellow pegs indicating the same information as the electric light bulbs. Mr. Harris Reinhardt and Mr. Earle Benson, the originators of this use of color, made the following statement concerning its use.

> "The significance of the pegs is readily grasped by persons who have no knowledge or charting techniques and to whom a regular control chart would appear complex and uninteresting."[1]

II. Color Aids Roaming Process Inspection

Another company was having trouble with its process-inspecting where the inspectors roamed around the plant from machine to machine inspecting the work of

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each machine. The troubles stemmed from the fact that many pieces were spoiled between trips of the inspectors and no indication of conditions was left for the next inspector. To help overcome some of this condition, colored tags were designed to positively and quickly convey to the inspector the conditions at the machine, thus indicating the type of attention that must be given each particular machine. Therefore, if the inspector saw green tickets he knew that the machine had been consistently turning out good work and that at the last inspection it was still in good shape. If he saw a yellow ticket on the machine he knew that at the last inspection the machine was pushing toward the limits of acceptance and that the operator had been notified to have the difficulties corrected. If a red ticket was on the machine then the inspector knew that the machine had been ordered shut down by the previous inspector because of faulty material. Thus the inspector knew the story at each machine at a glance and could govern the action he must take at each one. Also, the worker is notified by the tag the results of his work thus preventing buck passing by the operators. As in the case of Sylvania, this system also served as a non-financial incentive as the workers vied with each other to keep a green ticket on their machines and as soon as any other ticket appeared the machine operator took immediate steps to correct it and regain his position among the other workers.[1]

1. Buckingham, Earle, "Production Engineering", 1942,pp.148-149.

Another company using roving inspectors found that a considerable amount of idle machine time was caused by the worker being unable to locate quickly an inspector to check his sample pieces and authorize his resuming production after a new set-up or after being stopped because of poor quality. To overcome this, two things were done, both making use of color. First, the inspectors were given orange hats to wear whenever they were on duty in a department. This allowed the operator to spot an inspector more easily and quickly notify him that his machine was ready to go. Secondly, an orange light was placed over each machine which could be lit by the operator. As soon as he was ready to start operating he switched on the orange light. The inspectors were constantly on the watch for these lights and proceeded to them as soon as possible. The company found that its idle machine time from this cause dropped immediately.

III. Color Aids Inexperienced Personnel to Inspect

Another problem in inspection was the difficulty in training inspectors to read meters and gauges. During the war it was necessary to use personnel in an inspection capacity who had little technical background and whose knowledge of the products being inspected was very limited. Because most products are not inspected on exact scales

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but have various degrees of tolerances, it was found possible to indicate limits of good, bad, acceptable, and salvage by colors. Thus, on an electronic condenser tester the dial would be calibrated in colors instead of figures. When a condenser was placed across the poles of the tester it was acceptable if the needle on the dial rested on any area in green, rejected if the needle was in position over red, or capable of slavage if the needle rested over blue. The example of a condenser tester is merely one of a great many applications of color to this type of inspection where a dial can be used and where there is sufficient degrees of tolerance in the inspection to make the use of color practical.

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CHAPTER VIII

MISCELLANEOUS USES OF COLOR

I. Color and Records

Ever since the development of the first simple business form, management has been endeavoring to eliminate as much of the paper work and the accompanying detail as possible in production control, inventory and maintenance. Of the many ways that have been found to simplify paper work, color, has proven to be one of the most important. Color is used in practically all phases of production control, in purchasing, in the factory office, in the tool crib, stock rooms and store rooms, in the inspection booths, payroll department, methods department and employment. In fact, anywhere that records or forms are prepared, used and filed, we find color playing an important part.

Color can tell a reader of a form or record more at a glance than many lines or paragraphs of printed material. It conveys a complete story in a fraction of a second, clearly and concisely. Color is the efficiency expert of the written word. There are no set rules for the use of color in records or in the handling of records except that it be kept as simple as possible in order to be easily understood. Like anything else that is overdone, color will lose its effectiveness and become just

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another time consumer if it is allowed to become too complicated and involved.

Color plays its part in this phase of its activities as signals or tabs, colored forms, "Graph-A-Matic control"[1], tapes, inks, lights, stamps, etc.

In discussing the causes or reasons for irregularities in production on a graph or chart, C. E. Knoepple said,

> Color signals show in a most comprehensive and graphic manner the irregular conditions usually met within industry.[2]

II. Colored Forms

Colored forms are a universally accepted method of sorting, filing, and distinguishing paper work. It is effective in this use only as long as it does not become burdensome to those using them. W. C. Leffingwell and Edwin M. Robinson have this to say about the use of color informs,

> Colors should never be used in forms unless they are necessary for the purpose of a color system in which the various colors have a special significance.[3]

1. A trade marked system of card filing by Remington Rand, Inc.

2. Knoepple, C. E., "Graphic Production Control", 1920, p. 339.

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The "Handbook of Business Administration" states that it is preferable to avoid the use of color in forms as much as possible when it is to be used as an index to copies.[1] This idea of using colors in forms only where absolutely necessary is made more emphatic by F. J. Callanen, general forms control supervisor for Sperry Gyroscope Company, Inc. Mr. Callanen says,

> Colored stock we have found conducive to error because colors vary from one color to another, even from the same mill, and many people have trouble distinguishing between colors when used in multiple-copy forms.[2]

To me this is not a good reason for deciding not to make use of colored forms. If shades are kept far enough apart and similar shades are not used in the same form, such difficulties should be kept at a minimum and the results would more than outweigh this simple factor. Color is very effective in forms when used in one or more of the following ways:

1. To distinguish a copy where many similar copies are handled by any one department and where the printing is so small that a printed identification mark will not be easily visible.

2. When two similar forms appear in one place

1. Donald, W. J., Editor, "Handbook of Business Administration", 1931, p. 953.

2. "Form Standardization and Simplification", Office Management Series No. 110, American Management Association, November 1945, p. 51.

and quick distinction between the two is necessary as an aid in sorting operations or for some other reason.

3. To represent something distinctive or pertaining to a particular function or department.

4. If the form is to receive a great deal of handling, buff is most desirable for it reduces glare and does not soil as easily as white.[1]

Some companies assign an individual color to each form used in the plant. The color as well as the title help to decide the location in the plant where it is used. In many such plants the forms are picked up and distributed by messenger boys who make schedule trips to keep the forms moving and work flowing smoothly. In one plant the messenger boys distribute the forms in large envelopes to each department from a central sorting room. The material to be returned is ready in another envelope. Upon opening the envelope it is very easy for the department worker to quickly scan the forms and discover if there have been any mistakes made in giving him the wrong forms. The color of the forms is a good check on the accuracy of distribution and sorting. At the other end of the route the sorting room has a much simpler task. Forms do not have to be read nor does the sorter have to know too much about the activities of the department as the

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color indicates the various departments.[1]

Something extra has been added to the collection of mail in the office of Herbert B. Roth. Mr. Roth has had a number of red cards printed with the words "Last Collection of Mail Has Been Made". Thus when the messenger is making his last round of the day he drops one of these cards in each basket. A secretary who was absent from her desk when the pickup was made is reminded by this conspicuous notice that any remaining mail must be prepared for outside mailing and that it is her responsibility to see that it is taken care of. Mr. Roth found that this practically eliminated a bothersome delay in mailing due to the carry-over of late outgoing mail left on desks.[2]

III. Suggestion Systems

Colored forms can play an important part in making a suggestion system more effective as well as cutting down the time and effort necessary to carry such systems to profitable conclusions. Color makes the sorting of the suggestions easier, and quicker. Action can be taken on suggestions much more rapidly and effectively because the color of the form indicates the department of

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origin. When action has been taken it is quicker and easier to locate the person who originated the suggestion and advise him of the action taken.

The color of the forms may be used to designate many of the following items that must be known in order to effectively and efficiently handle suggestions:

1. To designate originating department and shift.

2. To designate type of suggestion in accordance with a given schedule, to aid rapid routing to persons or group handling that classification.

3. To indicate time periods (week, month, or months) for purposes of evaluating various suggestion plans.

4. To indicate length of time suggestion has been before the committee and thus encourage prompt action.

A typical case of successful application of colored forms to a suggestion system is that of the Illinois Central Railroad.[1] The Illinois Central Railroad is composed of fourteen divisions and personnel are more or less constantly on the move over several divisions in the course of their duties. It became difficult to handle suggestions as a worker might place a suggestion concerning one division in the suggestion box of another division miles away. It took time for the suggestion people to sort out the suggestions to the proper divisions. Many times suggestions

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concerning items in one division were forwarded to the wrong division and then had to be re-routed. In other cases, the suggestions were disregarded by divisions to which they were erroneously sent because the suggestion could not be applied in their division andtherefore it was written off as a bad suggestion. Realizing that their present suggestion system was discouraging suggestions rather than encouraging them, Illinois Railroad instituted a series of colored forms, a different color for each division in the railroad. It now was very simple to sort the forms and forward them to the proper divisions. Also, the men filling them out were sure that they would get to the proper division, merely by choosing the right color, no matter where in the railroad system they happened to be when they thought of the suggestion. Mr. H. C. Marmaduke, an Illinois Central Railroad official, claims the following advantages for this new system.[1]

1. Easier for personnel to submit suggestions.
2. Easier to file and handle.
3. Qucker action or suggestions received.
4. Men's morale up due to quicker action on their suggestions and the fact that they knew their suggestions were really being considered by the proper people.

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IV. Personnel Efficiency

Mr. C. E. Knoepple, in his book, "Graphic Production Control" uses a Gantt chart plus color to tell the production control department the status of its workers. This type of chart may be used as an individual chart for each man for any length of time or for a group or department for any length of time.

In this chart the length of space from the edge of the stub on the left to the end at the right, indicates an eight hour day and is divided into eight segments. From the left hand margin a black line is drawn indicating the number of hours the man actually worked. From the right hand margin toward the left, various colored lines are drawn to meet the black line indicating the delays and their causes. Each color stands for a different classification of delay.[1] Thus at a glance we can tell the efficiency of the worker and also obtain a good idea of the reason for the delays. Such a chart may be plotted for a group or department each day to show the efficiency of the department.[2]

This type of chart is often used as an incentive chart to build up morale and spirit among the workers. In such cases the line does not represent actual hours

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that can be worked by standard hours for a job. Each day the actual hours of work the department succeeded in obtaining is plotted. The colors help to show that it was not through the fault of the department that a task was not made. However, any difference between the end of the color line and the black line indicates that the department was not up to standard.

V. Work Simplification and Motion Study

One of the first ways that color found to play a part in this phase of industrial management was as a part of a system of motion analysis developed by Frank B. Gilbreth. Gilbreth found that all cycles of motion could be broken up into 17 elementary sub-divisions. These sub-divisions he called Therbligs. Each of these therbligs has a symbol and further each has a specific color to set it off from the others. Frank Gilbreth even went so far with this assigning colors to therbligs as to assign a specific Dixon pencil number to be sure that the proper color would be used. (See Exhibit I9, page 122).

These colors are used principally to aid in the drawing of simultaneous motion-cycle charts, better known as "simo-charts". In making the chart the various colors are used to indicate the sub-division of motions that were used and by the length of the colored line the length of

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time it took the operator to start and finish the subdivision.[1]

Ralph M. Barnes says,

> Color can be seen more quickly than shape; therefore, color should be used to aid in selecting or sorting whenever possible.[2]

This idea is very nicely applied to the sorting of photographic prints into the proper batches after the printing and developing process has been completed. The prints were stamped in different colored inks. The prints were therefore sorted by color and not by number. Such a sorting system proved far easier and much faster than sorting by letter or figures.[3]

Frank Gilbreth also recommended that the handles of tools be painted the same colors as the places where they are kept as this saves time when putting it away and finding it the next time.[4] This simple application of color is used whenever the operation is one which is highly repetitive. The Lynn Works of the General Electric Company in Lynn, Mass. makes use of this on several jobs where the operator does the same thing many times per day. The

1. Barnes, Ralph M. "Motion and Time Study", 1946, pp. 62-63 and 94-95.

2. Ibid, page 107.

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handles of the tools are painted the same as the holding devices which pre-positions them for the next operation. Also, the tool holder is arranged in such a manner that the use and return of the tool proceeds in a path from left to right. It is important, therefore, to take advantage of this bit of color sense so that the tools are always inthe proper order for the best possible motion economy. This painting of tools is, of course, very helpful in teaching new workers the job. All the worker has to do is remember the sequence of colors and not sizes and shapes of the tools.

Further use of color is made in radio manufacturing where to facilitate mass production and to allow people to assemble, who know nothing about how a radio operates, all wiring is colored a specific code. Thus a girl putting in a certain condenser knows only that she is to solder one lead to a red and white striped wire and the other lead to a blue and red wire. This use of color codes for wiring is used practically everywhere in the electrical industry where connecting of wires is done. The telephone lineman making repairs on main lines sometimes has the job of splicing together several hundred small wires. He is able to do this accurately, and quickly by the aid of color codes woven into the wires. It then becomes a simple matter to match up the proper wires.

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Resistors used in radio and electronic equipment are also color coded as to value, type and tolerances. Thus they may be sorted rapidly and efficiently. It would seem that learning a color code for the many values of resistors is hardly worth the time. But after a person has worked with the code and become familiar with it, it is far easier and less strain on the eye to merely spot a maximum of four colors on the resistor to sort it properly. Color coding of electronic wiring and resistors is a helpful cost-reducing and time-saving device.

VI. Temperature Control

Color engineers are able to perform some of their most useful work, not with the many light colors we have heretofore discussed, but with pure black and white. Their work is based on the physical property that black will absorb heat and white will repel it.

One striking illustration of the application of this property of black and white may be found at the Beech-Nut Packing Company, Canajoharie, New York. During the summer months the roofs of all company buildings are painted with a short-lived water soluable paint. This simple application lowers the temperature by several degrees during the hottest parts of the summer. By fall the white paint has weathered off and the black tar roof absorbs the heat

of the sun and raises the plant temperature several degrees.[1]

The principles of absorption and repulsion of heat by the use of color is also applied by heating engineers to radiation. For example, wall areas immediately in back of radiators are painted white or aluminum to reflect the heat out into the room where it gives the most benefit. In addition, heating engineers have found that a five coil steam radiator painted white will produce as much heat as six coils painted black.[2]

Manufacturers of automobiles have found that dealers and customers alike in tropic countries as well as southern United States prefer light-colored cars as they absorb less heat and are several degrees cooler than a dark, deep-colored car.

VII. Power Outlet Color Code

Many plants have need for several different types of electrical power, i.e. direct, alternating, 60 cycle, 50 cycle, 110 volt, 220 volts, 600 volts. In many plants these various types may number as high as 10 or 12. With the numerous outlets required for the different types of power, easy identification for employees and maintenance crews becomes a necessity. At the RCA Victor, Camden, New Jersey plant each manufacturing department has as many as six different types of power and in some there are as many as fourteen.

1. Stouffer, Lloyd, "Color Punches the Time Clock", p. 126.
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Before application of the present color code as an aid to the identification of each outlet, there were numerous injuries to personnel and damage to equipment by plugging into the wrong power supply. RCA Victor developed a color code which is now being applied to all outlets as a regular part of its plant maintenance program. The code calls for solid colors to be applied to all alternating, 60 cycle circuits as they are more numerous. A different color, however, is applied to each alternating voltage. All direct current circuits and those other than 60 cycles are painted with diagonal stripes. Colors indicating the voltage are the same as those for alterating and form the background color. The diagonal stripe indicates the number of cycles, with a different color for each type in the plant.

All outlet boxes, receptacles, drop cord attachments, and switch boxes were coded first. Also being coded are all the portable electrical units in the plant, plus all tie lines and control boxes.

Since the application of this simple color code, accidents to personnel and damage to equipment have dropped off sharply.[1] Users of such a system are cautioned, however, that simply coloring power outlets is not all that should be done to completely eliminate such accidents. It is far

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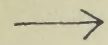
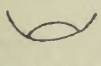
EXHIBIT 19

STANDARD COLORS FOR THERBLIGS

Symbol	Name of Symbol	Name of Color	Dixon's Pencil Number
	Search	Black	331
	Find	Gray	352½
	Select	Light Gray	352½
	Grasp	Lake Red	321½
	Transport Loaded	Green	354
	Position	Blue	350
	Assemble	Violet	323
	Use	Purple	323½
	Disassemble	Light Violet	323
	Inspect	Burnt Ochre	335½
	Pre-Position	Sky Blue	320
	Release	Carmine Red	321
	Transport Empty	Olive Green	325
	Rest	Orange	324
	Unavoidable Delay	Yellow Ochre	324½
	Avoidable Delay	Lemon Ochre	353½
	Plan	Brown	343
	Hold	Gold Ochre	388

Source: Barnes, Ralph M., "Motion and Time Study"

CHAPTER IX

CONCLUSIONS

It is now a matter of record that the use of color in industrial management is paying dividends in improved working conditions, good housekeeping and substantial increases in production. Every day industrial management is finding new and improved uses for this new science and tool of management. It was with difficulty that the author was able to keep this study up to date as each month brought forth new articles on color and its uses in industrial activity.

Color, if used wisely and with restraint, can and will accomplish what may seem like miracles to many who do not realize the power of color. But if color is . to be successfully applied it must be done scientifically and not without sufficient study to analyze all its various facets. Also, the users must realize that it is not simply a matter of splashing paint around or tying pretty colored ribbons or tags on items that makes color work. The user is cautioned that his color program must be coordinated with a planned program of improvement throughout the plant to reap a full harvest of color dividends.

There is no doubt that color properly coordinated with light can increase illumination and change drab interiors to cheerful, pleasant places in which to work. Such a

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program can increase production, reduce eye fatigue and prevent accidents. The following statement made by George H. Fry, Jr., of the Brown Instrument Company of Philadelphia, Pennsylvania is typical of the results of color conditioning.

> Painting machinery in functional colors to highlight working surfaces, emphasize moving parts, and clearly define danger points has contributed to higher production and less eye fatigue.[1]

The application of color conditioning principles to plant painting is revoluntionary when we consider that since the factory came into being with the Industrial Revolution it has always been considered a waste of time and money to do more than just keep the plant clean. Dark colors were favored to reduce maintenance cost and any changes in this idea were only made as concessions to lighting. Today, however, we find that color is accepted as having a definite place in factory life and that merely keeping the plant clean is not enough. Industrial management has realized that color can do much to increase morale by making the plant a better and more cheerful place to work.

At the present time it is possible in any industrial city or area to readily pick out those plants who are applying color conditioning, but it is the author's

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In concluding this study the author wholeheartedly approves of the use of color in industrial management and urges that more industrial managements take the time to investigate the possibilities of adapting all or part of the uses set forth in the preceding pages. In this day and age when management is constantly looking for new ways to produce its products more efficiently and at less cost, the science of color, as applied to industrial activity, offers many chances to fulfill this desire.

There is, of course, always the danger that some managements will take on color without properly evaluating and studying it. This will, of course, lead to confusion and will defeat one of the prime factors in color conditioning, that of orderliness. Too much color can be just as bad, or even worse, than no color at all. In fact, color poorly or improperly used may even increase costs or lower production. There are at the present time trained, competent color engineers who understand the use of color and who can correctly apply it to almost any use to produce the best effect.

Planning color for industrial interiors and equipment is a matter of sound engineering rather than merely an artistic venture. The idea of dressing up a plant in gay

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Planning color for industrial interiors and equipment is a matter of sound engineering rather than merely an artistic venture. The idea of dressing up a plant in gay

colors may sound attractive, but before the decision is made it will be well for management to consider the following fundamental questions.

1. What are we painting for?
2. What will we gain by using color?
3. What will we lose by using color?

In obtaining the proper answers to these three questions, management will be forced to consider all the angles of color application and the resulting decision should make for a satisfactory and successful use of color.

Industrial American has progressed in great strides before the industry of the world, not only because of its excellent materials and workmanship, but because management has had the foresight to look ahead and to see the value in trifles - tremendous trifles. The outlook of American industry in the coming years is bright and color will help to make it brighter and increase the illumination along the way to bigger and better achievements.

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